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EFFECTS OF PULP MILL WASTES ON RECEIVING WATERS AT WARD COVE, ALASKA

Federal Water Quality Administration
Anchorage, Alaska

October 1970

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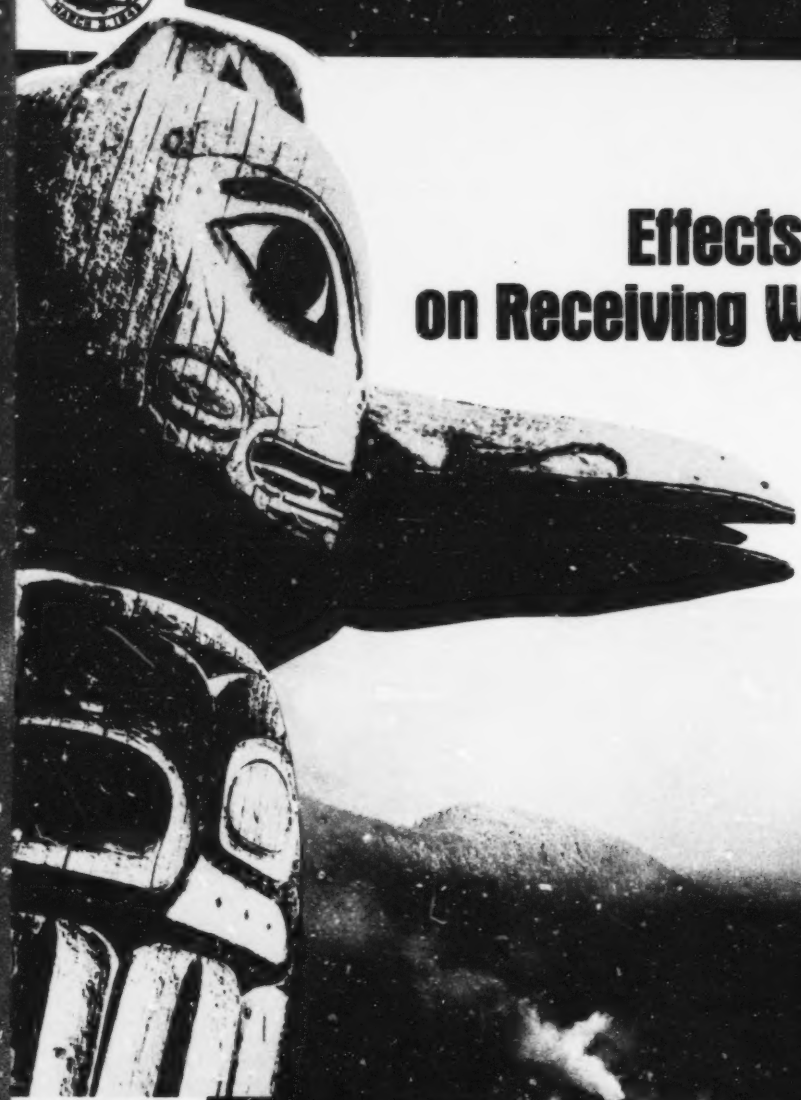

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CLEAN WATER

OCTOBER · 1970

EFFECTS OF PULP MILL WASTES

ON

RECEIVING WATERS AT WARD COVE, ALASKA

Details of illustrations in
this document may be better
studied on microfiche.

UNITED STATES DEPARTMENT OF THE INTERIOR
FEDERAL WATER QUALITY ADMINISTRATION
NORTHWEST REGION
ALASKA OPERATIONS OFFICE
ANCHORAGE, ALASKA
OCTOBER, 1970

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INTRODUCTION

Problem

Alaska has many water quality problems associated with industrial developments in estuarine areas. The water quality standards that have been adopted by the State have been approved, with exceptions by the Federal Government, to protect these estuarine water resources for present and future uses. To assure compliance with the approved standards, the adequacy of industrial waste treatment and disposal systems at Ward Cove was evaluated.

The Ketchikan Pulp Company operates a magnesium base bisulfite process pulp mill at Ward Cove. Current production is about 580 tons of pulp per day, but increased production is anticipated. The mill presently relies upon chemical recovery units and screening before discharging wastes into the waters of Ward Cove. The effluent from the mill still contains, however, significant amounts of sulfite waste liquor (SWL) and settleable organic solids. The treatment requirements in the water quality standards adopted by the State of Alaska stipulate:

> Secondary treatment is required for all industrial and municipal waste unless engineering studies approved by the Department of Health and Welfare, and where interstate waters are affected, concurred in by the Federal Water Quality Administration, show that the water quality standards can be met with primary treatment. Primary treatment is the minimum acceptable treatment (1).

The effects of the Ketchikan Pulp Company's discharges in Ward Cove were investigated in 1968 and 1969 by the Federal Water Quality Administration in cooperation with the U.S. Fish and Wildlife Service. Water quality data from this investigation, and from previous studies by the State of Alaska and the Federal Water

Quality Administration, established the significance of changes caused by long-term discharge of pulp mill wastes to the waters of Ward Cove.

Objectives

The objectives of this study were to determine:

1. What is the present water quality in Ward Cove relative to the water quality standards?
2. What is the magnitude of the effect of industrial waste discharges on the aquatic environment of Ward Cove?
3. What changes in industrial operation should be made to eliminate or significantly reduce water quality degradation in Ward Cove?

Scope of Study

Chemical, physical, and biological data were collected from Ward Cove and the adjacent waters of Tongass Narrows. The parameters were selected to define the effects of only the pulp mill wastes, and no direct attempt was made to assess the impact of wastes discharged from a cannery also located in Ward Cove. Field work was accomplished May 10-15, July 3-8, October 8, 9, 10, December 18, 19, 1968 and April 12, 13, 14, and May 13, 1969.

Authority

Section 5 of the Federal Water Pollution Control Act, as amended, authorizes the Secretary of Incerior to conduct studies relating to the causes, control, and prevention of water pollution. The study was requested by the Alaska Department of Health and Welfare.

FINDINGS AND CONCLUSIONS

The findings revealed that the level of treatment provided by the Ketchikan Pulp Company is insufficient to insure compliance with the Alaska Water Quality Standards.

Typically high sulfite waste liquor (SWL) concentrations were present in the 1.4 square-mile area of Ward Cove and Tongass Narrows. Of 276 samples taken in the top 20-meter layer in this area from May 1968, through May 1969, 50 percent had SWL concentrations greater than 44 parts per million (ppm), 35 percent greater than 100 ppm, and 11 percent greater than 500 ppm.

The SWL discharged into Ward Cove, the organic bottom deposits, and the inability of the Cove water to effectively disperse and assimilate the SWL combine to reduce the dissolved oxygen concentrations in Ward Cove and adjacent waters on a year-around basis. During the late spring, summer, and fall, when exchange of waters between Ward Cove and Tongass Narrows is at a minimum, the dissolved oxygen content of these waters is reduced below 6 milligrams per liter (mg/l), the minimum level allowed by the Alaska Water Quality Standards.

The toxicity of SWL to phytoplankton and the reduced light penetration caused by SWL and log rafts combine to reduce the productivity of these waters. SWL concentrations of 50 ppm, known to be toxic to phytoplankton and salmon fishfood organisms, were found throughout Ward Cove, and extended significantly into Tongass Narrows. Ten parts per million SWL, shown to be damaging to immature

forms of indigenous fish and shellfish occurred over an even greater area. Light transmittance was reduced as much as 43 percent near the waste outfall, and by 14 to 25 percent near the mouth of the Cove.

The discharge of SWL from the pulp mill significantly reduced populations of blue mussels throughout 50 percent of the littoral reaches of Ward Cove. Additionally, waste discharges produced sludge deposits that blanketed much of the bottom of the cove and prevented the establishment of the variety of bottom-associated organisms that are found in similar, but unpolluted, water.

RECOMMENDATIONS

1. The Ketchikan Pulp Company should take immediate steps to:

a. By 1972, provide primary treatment of wastes to remove all settleable solids and at least 70 percent of volatile suspended solids. Primary treatment by 1972 is called for in the Implementation Plan for the State of Alaska. The established deadline should be met.

b. Modify log handling practices to minimize accumulation of wood solids in Ward Cove. Log storage and handling contribute a significant amount of organic debris to the bottom deposits in Ward Cove. A program should be implemented to reduce log abrasion by minimizing log handling and storage in the water and developing land-based storage and handling capabilities.

c. Remove all existing sludge beds associated with mill discharge and log handling. These highly organic deposits should be removed entirely from the water and disposed of on land in a suitable containment area. Removal should be accomplished during biologically non-critical periods and conducted in a manner to minimize water quality degradation.

Implementation of these recommendations will result in an immediate improvement in dissolved oxygen levels and aesthetic appearance within Ward Cove.

2. Develop and implement a program to insure that sulfite waste liquor (SWL) concentrations do not exceed 10 parts per million (ppm) in the surface ten meters of Ward Cove and Tongass Narrows. Included in this program must be the following specific steps:

a. Construction of an outfall line in the main channel of Tongass Narrows. The design of the outfall line and diffuser shall be based on meeting the 10 ppm SWL concentration outside a very limited dispersion zone.

b. Provision of adequate storage capacity at the mill to insure that, in the event of equipment failure, etc., strong waste liquors are not discharged to the receiving waters without treatment or recovery.

c. Modification or improvement in plant processes and housekeeping procedures to minimize losses of SWL.

3. Prepare and submit to the State and Federal Regulatory agencies for review the following:

a. Proposed schedule for implementing the recommendations outlined in 1 and 2 above.

b. Detailed plans for the studies required to support design of the outfall system.

4. The Ketchikan Pulp Company must comply with the Alaska Water Quality Standards by providing secondary treatment, unless it can demonstrate that primary treatment will meet water quality standards. Such evidence should include a study and monitoring program to evaluate compliance with water quality criteria in both Ward Cove and Tongass Narrows. Study plans must be submitted to the State and Federal Regulatory agencies for approval.

STUDY AREA

General Description

Ward Cove is an estuary located about 5 miles north of Ketchikan (Figure 1), connecting with Tongass Narrows. The cove is about 0.5 of a mile at its widest point and 1 mile long; it is 0.3 of a mile wide at its mouth. It is about 55 meters deep at the mouth, becoming relatively shallow at the head of the cove with a depth of 5 to 10 meters. The cove covers an area of about 0.46 square miles. Ward Creek enters at the head of the cove and is the principal source of fresh water.

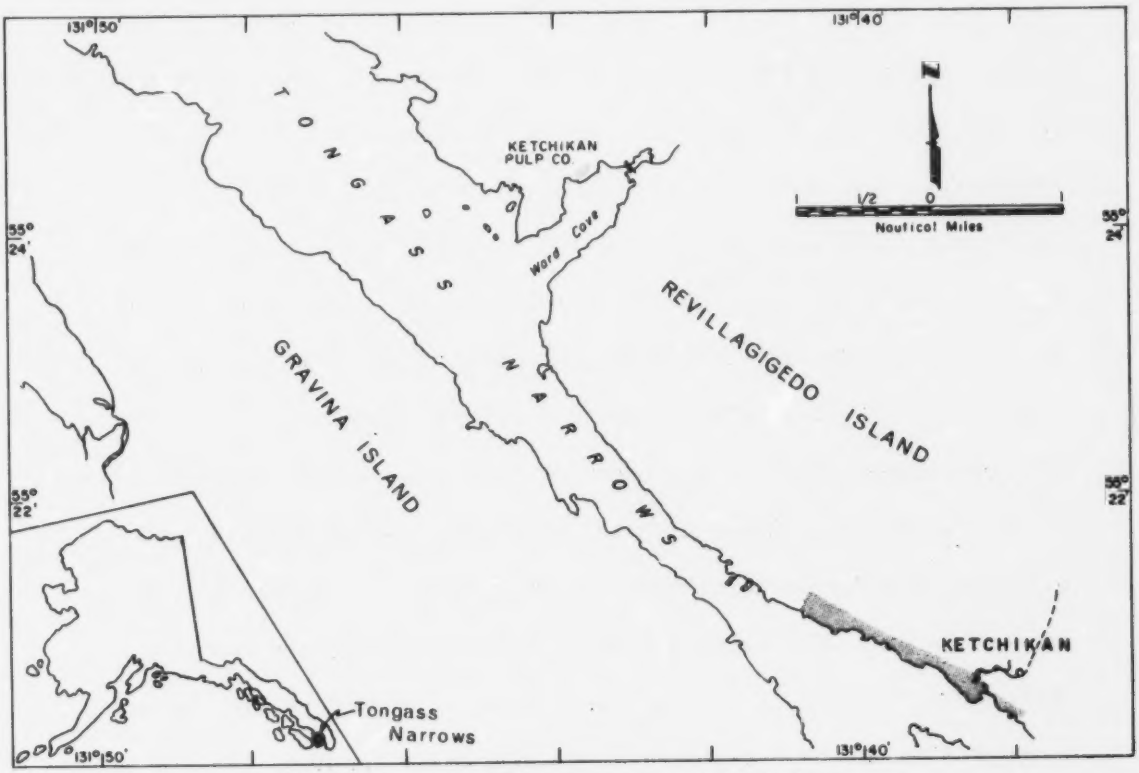

FIGURE 1. Tongass Narrows and Ward Cove.

Smaller streams enter the cove along the south shore. Ward Creek is regulated by a dam and the associated reservoir is a water supply for the mill.

Industrial development around Ward Cove, other than Ketchikan Pulp Co., consists of the Ward Cove Packing Co. and an abandoned fish reduction plant. Only a few homes are located near the head of the cove and along the south shore.

Climatic Conditions

The Ketchikan-Ward Cove area is in the cold maritime belt of Southeastern Alaska. Average rainfall is 150 inches annually, and annual snowfall is less than 50 inches. Prevailing winds blow from the southeast and occasionally from the northwest. The mean low temperature for January is 28°F, and the mean high is 38°F. Ice rarely forms on the marine waters of Ward Cove and Tongass Narrows.

The input of non-brackish water to the cove comes mainly from the mill outfalls and Ward Creek. The flow of waste water from the pulp mill is about 45 million gallons per day (mgd), or 69 cubic feet per second (cfs). Ward Creek in 1957 had a yearly mean discharge of 46 cfs, with a maximum daily flow of 1200 cfs and a minimum of 0.8 cfs. The discharge of water from Ward Creek is partially dependent on pulp mill water use since the Creek serves as the pulp mill water source. The daily water input to Ward Cove fluctuates between 1296 and 69.8 cfs with an average daily input of 115 cfs

from both mill and natural sources. Watershed flow retention is moderate due to the heavy precipitation and steep stream gradient.

Oceanography

In marine waters of northern latitudes, annual variations in temperature and salinity cause seasonally characteristic density profiles throughout the water column. Typically, during fall and early winter, the surface waters cool, become more dense than subsurface waters, and sink, causing complete vertical mixing. In winter, intense storms increase horizontal mixing. Tidal ranges at Ketchikan vary from a maximum high tide of 18.8 feet to a minimum low tide of minus 4.1 feet. A non-tidal current flows north-westerly through Tongass Narrows (10) past the mouth of Ward Cove. This current plus the tidal current gives an average velocity of 1.2 knots during flood which decreases to zero during ebb. Current measurements made in Ward Cove show a strong influence from eddies formed by the flow of water in Tongass Narrows past the cove. This suggests that dispersal of deeper waters from Ward Cove is largely by a process of eddy diffusion below the surface layer.

In the Ward Cove estuary, a surface layer of fresh water and mill effluent which is less dense than the subsurface layers results in the establishment of a stratified layer which persists throughout the winter and following summer. This stratification is

sufficiently well developed so that vertical mixing is greatly inhibited. Concentrations of pollutants in Ward Cove and adjacent waters are less in winter than in summer because of the increased rate of transfer from Ward Cove to Tongass Narrows as a result of the intense winter storms and the high runoff from Ward Creek.

Water Uses

Prior to the establishment of the pulp mill, Ward Cove served as a fish passage zone and nursery area. Some young salmon from Ward Creek still pass through the cove and sustain a small run, but the cove now is sufficiently polluted to preclude its use as a nursery area. Adult salmon utilize the deeper waters of the cove where little SWL occurs. It is doubtful they do more than pass through the area. Food organisms for salmon have been significantly reduced.

The recreational uses of Ward Cove have been reduced to limited sport fishing for salmon. Access for fishing is curtailed because logs often cover a third to a half of the cove.

Previous Studies

Water quality data for Ward Cove and Tongass Narrows collected between October 1, 1951 and September 30, 1952 (3), prior to construction of the pulp mill, show that the dissolved oxygen in surface water varied from a low of 7.8 mg/l during the winter to nearly

12 mg/1 during the spring. At the 50-foot depth, dissolved oxygen varied from 7.8 to over 10 mg/1. The five-day biochemical oxygen demand (BOD) was less than 2 mg/1, typical of clean waters. At the time of the 1951-1952 surveys, the only wastes discharged to Ward Cove were from the seasonally operated cannery and the fish wastes-reduction plant. Water quality degradation from these facilities was highly localized and mostly seasonal, and was evidenced by reduced populations of aquatic life. Other portions of the cove, however, supported a great variety of marine organisms indicative of clean waters.

Data from unpublished reports from the State of Alaska document the onset of water quality deterioration in Ward Cove between 1952 and 1960, after the Ketchikan Pulp Company began discharging wastes (4). Biological data in these reports show a decline in the number and kinds of marine organisms, and sludge accumulation with associated putrescent odors of hydrogen sulfide.

Studies conducted during August 1965 (5) revealed extremely high SWL concentrations throughout the surface waters of Ward Cove. The threshold toxicity of SWL to salmon fingerlings, herring, candlefish, euphausids, copepods and mysids was exceeded. The study also showed dissolved oxygen in Ward Cove was considerably degraded when compared to Tongass Narrows. The degradation ranged from 4.7 to 1.5 mg/1 at the surface, 0.6 to 1.6 mg/1 at the 10-meter depth, and 1.0 to 2.5 mg/1 at the 40-meter depth. The degradation was

attributed to the combination of effluent BOD, sludge-bed BOD, and the inhibiting effect of pulp mill wastes on phytoplankton. Throughout much of the cove the dissolved oxygen levels were less than the recommended value of 6 mg/l. The pH ranged from 6.94 to 7.12 in the cove, and in Tongass Narrows from 7.68 to 8.02. The Ward Cove pH values were below those for unpolluted sea-waters, and were caused by the combined effects of a low pH effluent diluted into the surface waters, excessive CO_2 from biochemical waste decomposition, and reduced photosynthesis.

WATER QUALITY STANDARDS

The State of Alaska Water Quality Standards (1) designate all marine waters, including Ward Cove, as Class D and E. Beneficial uses of marine waters include growth and propagation of aquatic life and waterfowl, fur-bearers and other water-associated life. The standards associated with marine waters that are of particular interest in this study are those for dissolved oxygen, residues in the form of floating solids and sludge deposits, toxic substances and aesthetic considerations.

Dissolved Oxygen

Class D - greater than 6 mg/l in salt water. Minimum of 7 mg/l in fresh water.

Class E - greater than 6 mg/l saturation in the larvae stage; greater than 5 mg/l in the adult stage.

Residues

Class D - none alone or in combination with other substances or wastes as to make receiving water unfit or unsafe for the use indicated, except that no waste oils, tars, greases or animal fats are permitted.

Class E - no visible evidence of wastes. Less than acute or chronic problem levels as revealed by bioassay or other appropriate methods.

Toxic Substances

Class D - shall be absent or below concentrations affecting public health or the ecological balance.

Class E - less than acute or chronic problem levels as revealed by bioassay or other appropriate methods.

Aesthetic Considerations

Class D and E - shall not be unreasonably impaired by the presence of materials or their effects (excluding those of natural origin) which are offensive to the senses of sight, smell, taste or touch.

WASTE SOURCES IN WARD COVE

Ketchikan Pulp Co.

Ketchikan Pulp Co. is a magnesium-base, bisulfite process pulp mill. The mill normally produces about 580 tons of dissolving grade pulp per day. Current major expansion of the mill includes a new digestor and will increase this tonnage figure. Recovery units are employed to collect, concentrate, and burn the strong pulping liquor. In the process magnesium oxide and sulfur dioxide are partially recovered for recycling. Primary treatment of the plant effluent is not provided.

Even though chemicals are recovered and the concentrated strong liquor and woodroom wastes burned, enough wastes are discharged into Ward Cove to have a serious impact on these waters. All wastes from the mill are combined and discharged to Ward Cove through two outfalls. The main sewer (Figure 2) discharged about 95 percent of the BOD and SWL loading, and over 80 percent of the volatile suspended solids. The woodroom sewer contains the remainder of the wastes, which are derived mainly from debarking operations and the magnesium-oxide recovery process.

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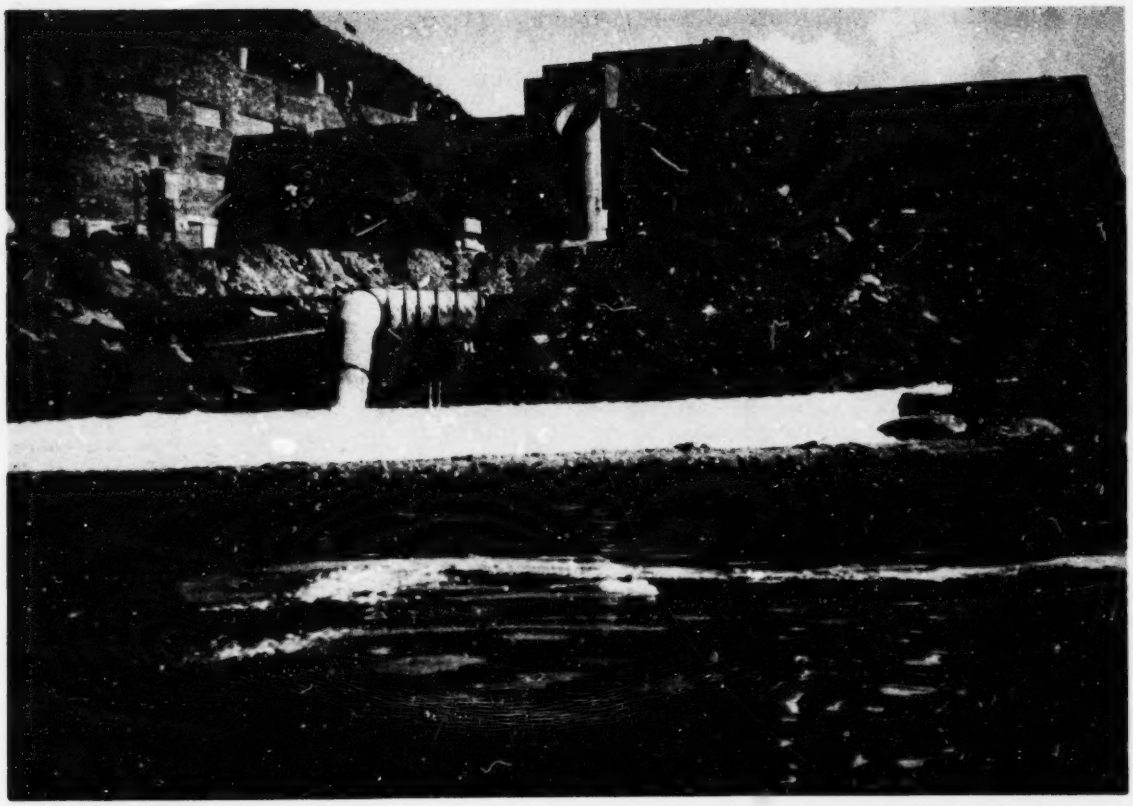

FIGURE 2. Main sewer outfall, Ketchikan Pulp Company

The cove in the vicinity of the woodroom sewer and the log-haul must be dredged periodically. The dredged sludge is hydraulically washed into deeper water near mid-cove (Figure 3).

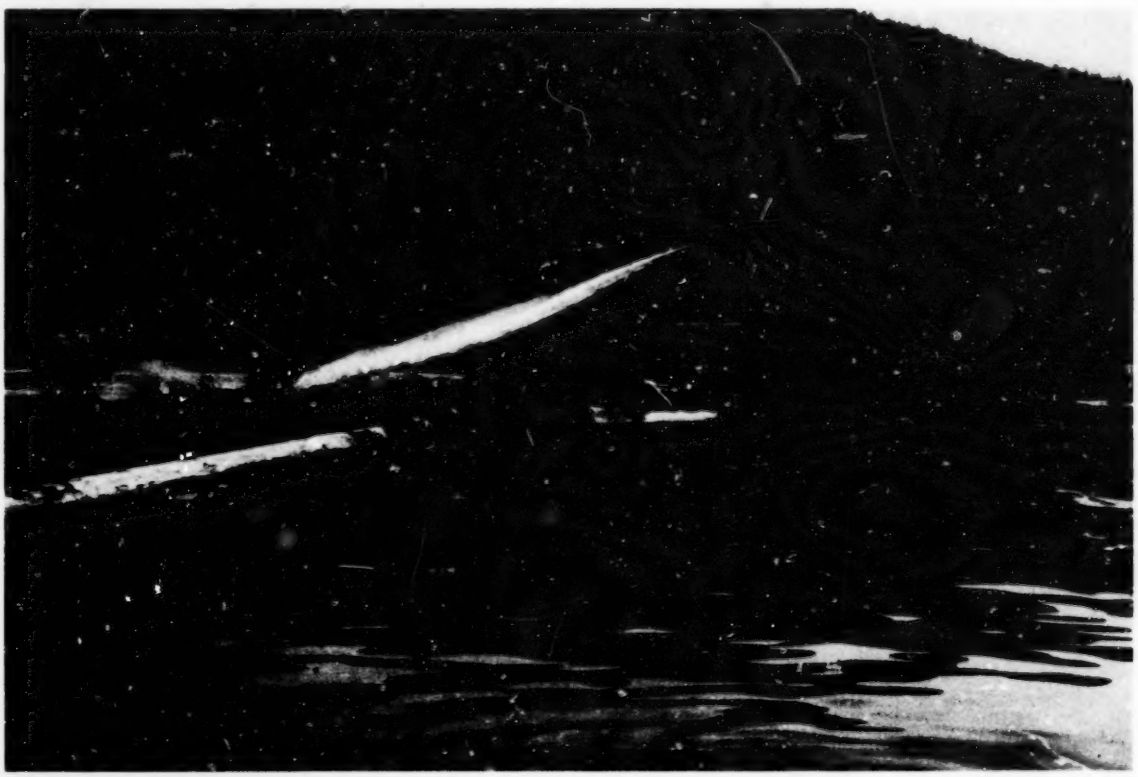

FIGURE 3. Sludge dredged near woodroom sewer outfall, is hydraulically washed into Ward Cove near Station 5.

Based on an inplant survey completed in October 1963 (5), the main sewer discharge had the following characteristics:

Parameter	Average Concentration
5-day BOD	610 mg/1
COD (chemical oxygen demand)	1940 mg/1
Sulfite waste liquor	7285 mg/1
Suspended volatile solids	160 mg/1

There are no facilities, such as a lagoon, for storage of strong liquors when the recovery units are by-passed. Thus, main sewer waste concentrations greatly exceed the average values when the recovery units are by-passed. A concentration of 18,000 ppm SWL was found in one sample taken from the main sewer boil July 3, 1968.

Logs often occupy about one-third to one-half of the surface area of the cove (Figure 4). Present log storage and handling techniques

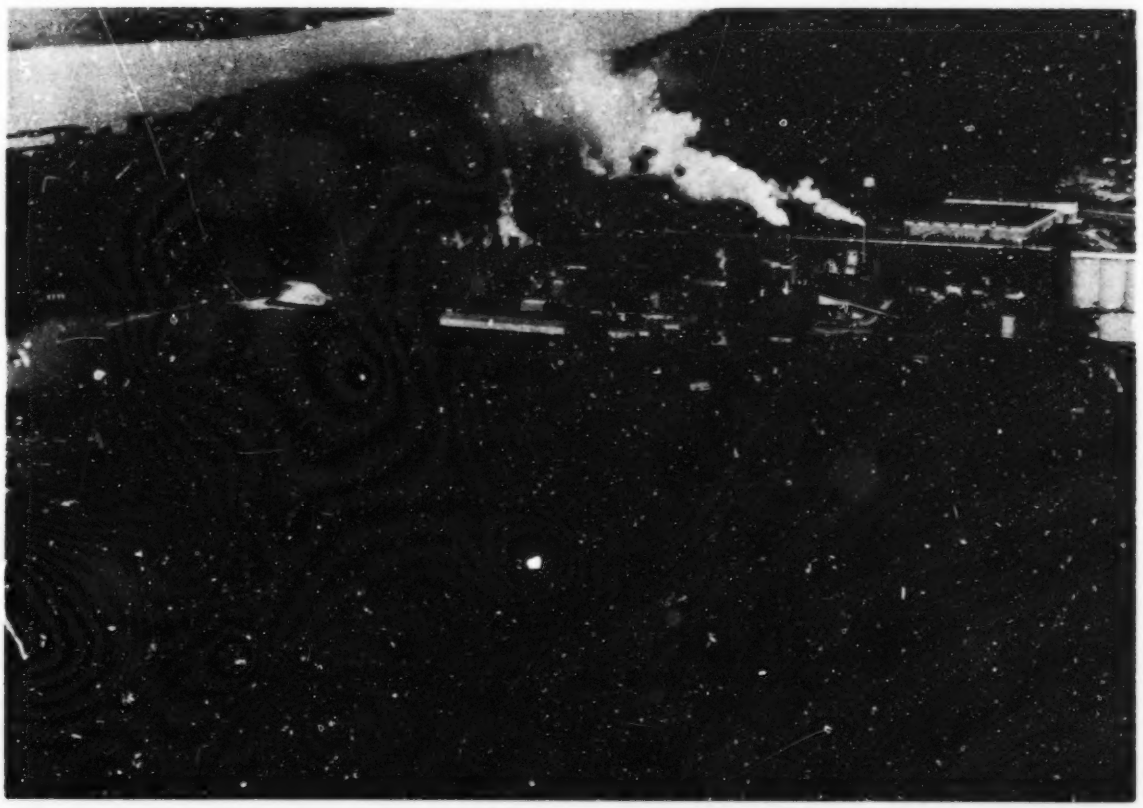

FIGURE 4. Ketchikan Pulp Co. and log storage in middle head reaches of Ward Cove.

contribute wastes to Ward Cove in the form of wood solids. Logs and debris have become water-logged and have sunk to the cove bottom. Logs stored in the shallow water at the head of the cove become beached on the ebb tide, blocking portions of the cove and Ward Creek for other legitimate uses.

Ward Cove Packing Company

Fish processing wastes from the Ward Cove Packing Company are disposed in the cove untreated. Operation of the packing company is limited to the salmon fishing season, generally from July through September.

Although the influence of the cannery was not directly evaluated in this study, data from previous studies, as stated earlier, show that the adverse effects of waste from the cannery were highly localized (3). Additionally, data gathered from the present study during July 3 through 8, 1968 when the pulp mill was shut down and the cannery was operating, revealed that dissolved oxygen in Ward Cove increased by 59 percent at the surface and by 21 percent at the 20-meter depth. As a consequence of the pulp mill shutdown and natural flushing in the estuary, by July 8 dissolved oxygen in the upper 20-meters had increased to a level that was equal to or exceeded the minimum standard of 6 mg/l. The adverse effect of cannery wastes were considered to be significantly less than those of the wastes from the Ketchikan Pulp Company.

SAMPLING PROGRAM

The first phase of this study was conducted in cooperation with the staff of the U. S. Fish and Wildlife Service, Auke Bay Biological Laboratory. This phase included two trips in 1968, one in spring, the other in summer, to collect data on dissolved oxygen, SWL, temperature, salinity, water currents and marine life in Ward Cove and the adjacent waters of Tongass Narrows. After the data from these two trips were evaluated, it was decided that FWQA would continue the study to document conditions in the fall and winter, and again in spring.

Sampling Stations

Fifteen stations were established within Ward Cove and the adjacent waters of Tongass Narrows (Figure 5). Since SWL concentrations below the 10-meter depth were generally less than the lower limit of accuracy of the analytical method, routine sampling for SWL was restricted to the top 10 meters; dissolved oxygen (DO) measurements were made at various depths.

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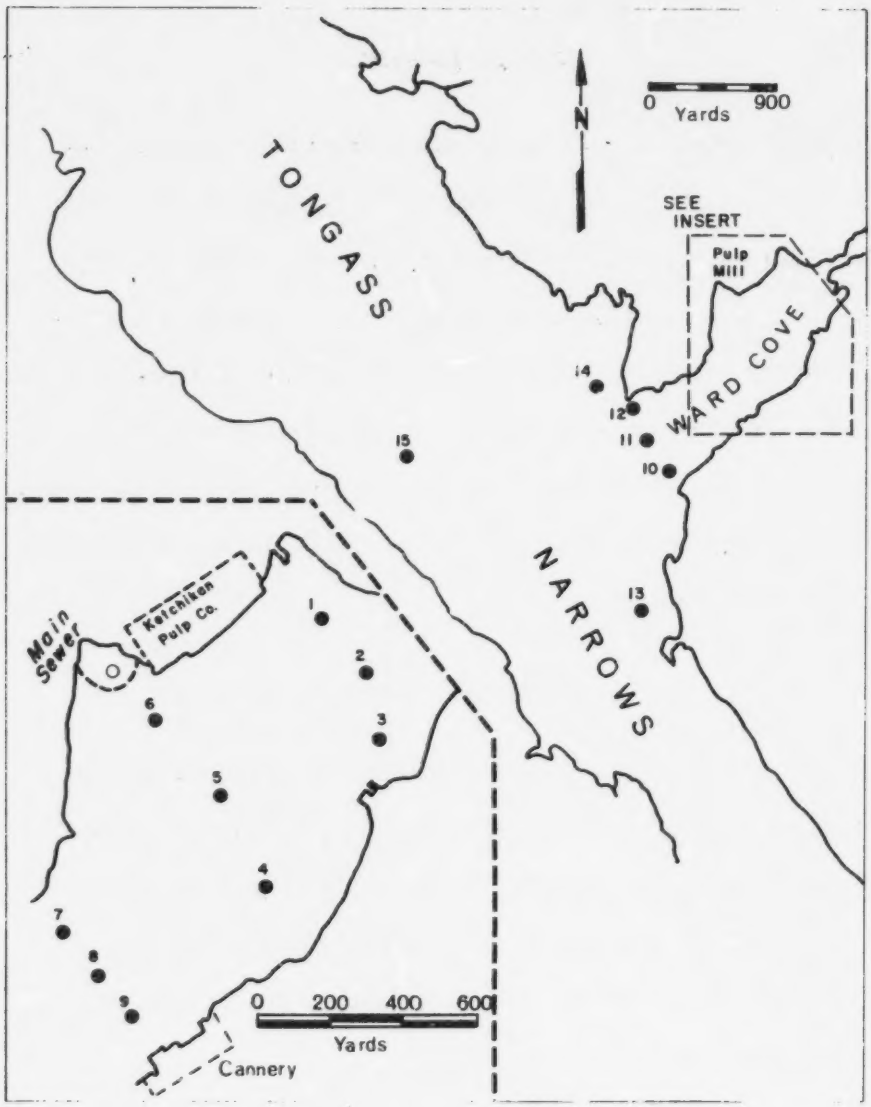

FIGURE 5. Location of sampling stations in Ward Cove and Tongass Narrows.

Temperature and salinity data were obtained throughout the entire water column during the first two trips. On later trips these data were obtained only in the surface waters (down to 15 meters) because the main interest was stratification within the surface waters. Current data were obtained at Station 8 during the July 1968 trip only. Biological sampling was accomplished on various trips to the area. Benthic samples were collected at Stations 2, 5, 6, 8, 9, 10, 11, 13, and 14. Samples of the blue mussel Mytilus edulis were collected at sites 1 through 10.

Sampling Periods

Sampling trips were scheduled throughout the year to determine the seasonal variation of water column stability and its correlation with the DO and SWL concentrations within Ward Cove. The sampling periods are shown on Figure 6. Obtaining a set of samples sometimes required sampling over an entire tidal cycle. Thus, samples for chemical determination were obtained at various tidal phases as shown on the Figure.

Methods

Water samples were collected with Nansen bottles and subdivided into appropriate 250 or 500 ml containers. Because of the possibility of SWL interfering with the oxide modification of the Winkler method, a Yellow Springs Instrument Model 54* and an Electronic Instrument Limited Model 15A dissolved oxygen meters were used.

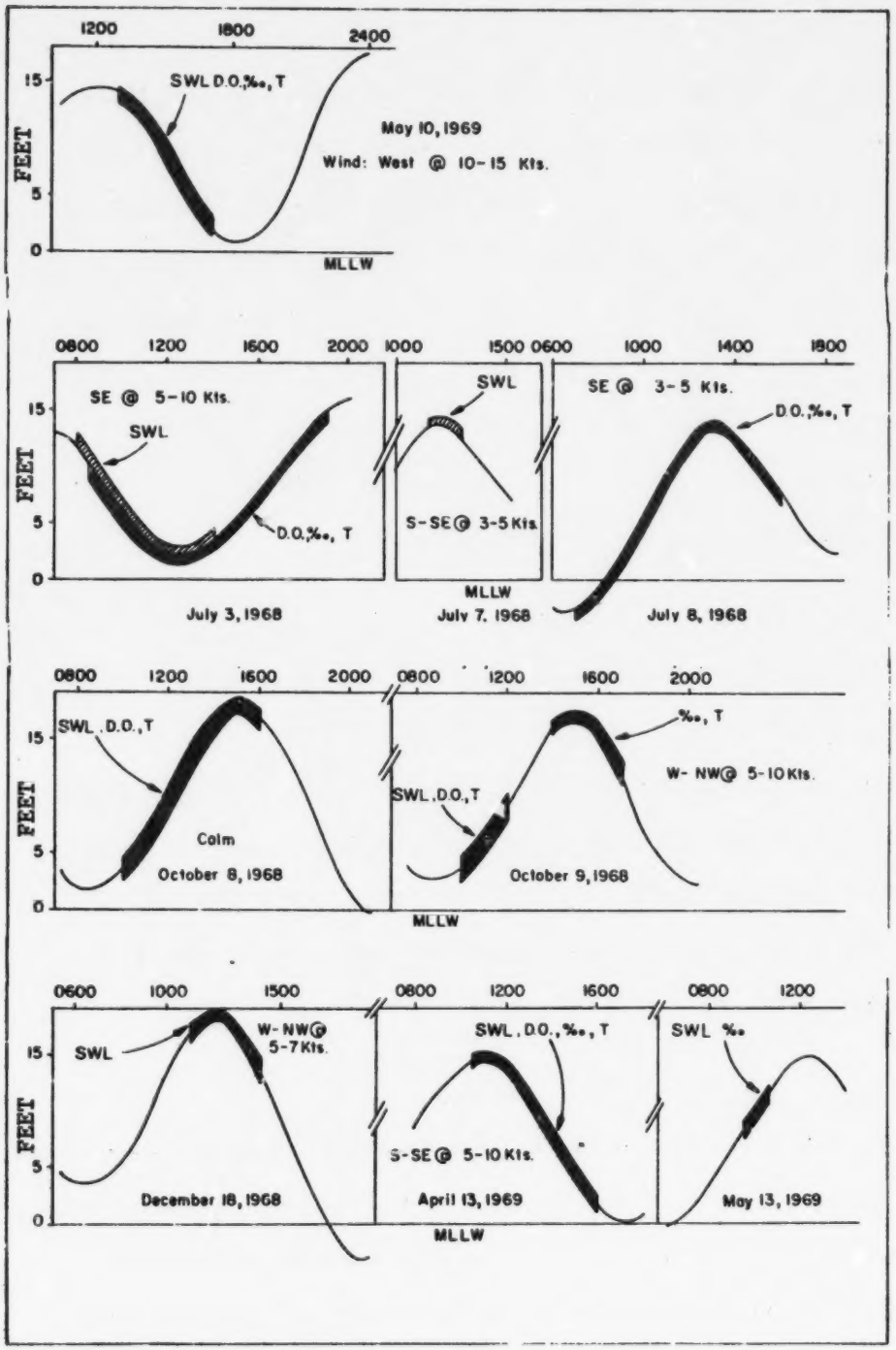

FIGURE 6. Sampling periods with respect to tidal phase, stage height and wind intensity and direction.

The dissolved oxygen probes were routinely calibrated against the Winkler method. Temperature data were obtained either with the above dissolved oxygen meters, a Beckman Instruments Model R55-3 Portable Salinometer, or with a bathythermograph. Salinity (°/oo) measurements were made with the salinometer, by titration with silver nitrate (6), or by hydrometers.

Transmissivity readings were made with a Hydro Products Model 410-BR Transmissometer using the Model 411 10 cm path underwater sensor.

SWL concentrations were measured using the Pearl-Benson Index (7), and were based on the spectrophotometic determination of the ligin-sulfonate concentration of the samples relative to a reference solution containing 10 percent dry solids by weight of calcium-base sulfite waste liquor. As a quality control, standards of various SWL concentrations were handled exactly as the samples: i.e., frozen and shipped to the laboratory along with the samples.

The SWL analyses were conducted either in the laboratory, on board the survey boat or, after preservation by freezing, at the Alaska Water Laboratory in College.

*Use of product and company names is for identification only and does not constitute endorsement by the Federal Water Quality Administration, U. S. Department of the Interior.

Bottom samples of muds and aquatic life were collected using a core-sample, a ponar dredge, and a Marukawa dredge. Samples were preserved and transported to the laboratory where they were analyzed. Standard techniques for counting and identifying organisms were used. Blue mussles, Mytilus edulis, were collected from inter-tidal reaches at low tide by two persons who in a half hour collected as many mussels as possible from the sector of greatest density at each of 10 sampling sites. The samples were preserved and taken to the Auke Bay Biological Laboratory for analysis.

Benthic organisms are valuable indicators of changes in water quality because their life cycles extend for one or more years and thus reflect water quality over a long period of time. Most bottom-associated organisms have limited methods of locomotion that restrict them to a specific area; thus, they are subject to adverse factors entering the area and can be used to delineate water quality. Changes in water quality sufficient to adversely alter the population structure of benthic organisms may also similarly modify other organisms such as plankton and fish.

RESULTS AND DISCUSSION

Temperature and Salinity

Water density data (σ_T values, Table 1, and Appendix, Tables A-1 and A-2), calculated for Stations 8 and 11 near the cove mouth from temperature and salinity determinations, show that the Ward Cove estuary was stratified so that a lens of less-dense poorly mixed brackish water overlaid subsurface and more saline waters throughout the year. Under these conditions, vertical mixing was inhibited and did not play an important role in the dispersion of pulp mill wastes from Ward Cove. Because of the lack of significant vertical mixing, wastes were dispersed primarily in the surface layer.

Exchange of Ward Cove waters with those of Tongass Narrows was caused by storm activities and by eddy currents. These eddy currents in the less-polluted, higher saline waters beneath the surface layer, are created by the northward flow of water in Tongass Narrows (10) past the mouth of Ward Cove. When storm activities were greatest, as in winter, the rate of exchange between Ward Cove and Tongass Narrows waters was greatest. During this period, SWL concentrations were lower than during spring, summer, and fall when storm frequency was lower.

TABLE 1.
TEMPERATURE, SALINITY AND DENSITY WITH DEPTH (METERS) AT STATIONS 8 AND 11, 1968-1969

Depth	May 15, 1968			July 3, 1968			December 18, 1968			April 13, 1969		
	T°C	o/oo	σt	T°C	o/oo	σt	T°C	o/oo	σt	T°C	o/oo	σt
						Station 8						
0	8.2	27.2	21.2	15.4	24.6	16.6	-	24.7		8.9	14.9	11.5
1	7.5	29.3	22.9	15.1	25.8	18.9	-	27.3		5.8	30.3	23.9
3	7.3	30.1	23.6	14.8	26.0	19.1	-	-		5.5	-	-
5	6.7	30.3	23.8	13.3	26.2	19.6	-	27.6		5.5	30.9	24.4
7	6.5	30.5	24.0	11.7	27.3	20.7	-	-		5.4	-	-
11	6.2	30.5	24.0	10.1	28.5	21.9	-	29.0		5.3	31.6	25.0
15	6.0	30.6	24.1	9.5	29.0	22.4	-	-		5.2	-	-
20	5.9	30.8	24.3	8.9	29.4	22.8	-	29.4		-	31.6	-
25	5.7	30.9	24.4	8.1	29.9	23.3	-	-		-	-	-
30	5.6	31.1	24.6	7.4	30.2	23.6	-	-		-	-	-
35	5.6	31.1	24.6	7.0	30.4	23.8	-	-		-	-	-
40	5.5	31.4	24.8	6.4	30.8	24.2	-	-		-	-	-
						Station 11						
0	8.7	24.1	18.7	14.8	26.4	19.4	5.9	26.3	20.8	7.9	26.0	20.3
1	8.4	27.9	21.7	14.7	27.4	20.3	5.9	27.0	21.3	6.0	30.3	23.7
3	7.2	30.3	23.7	14.6	26.8	19.8	6.0	-	-	5.3	-	-
5	6.6	30.4	23.9	13.6	26.7	19.9	6.4	28.5	22.4	5.2	31.3	24.7
7	6.5	30.5	24.0	12.3	27.0	20.4	6.6	-	-	5.2	-	-
11	6.3	30.6	24.1	10.8	28.4	21.7	6.9	29.0	22.8	5.1	31.7	25.0
15	6.1	30.7	24.2	10.0	29.6	22.8	7.2	-	-	5.1	-	-
20	5.9	30.8	24.3	8.6	30.0	23.3	7.3	29.2	22.9	-	31.6	-
25	5.7	30.9	24.4	8.1	30.5	23.8	7.4	-	-	-	-	-
30	5.7	31.2	24.6	7.4	30.8	24.1	7.4	-	-	-	-	-
35	5.6	31.2	24.7	6.9	31.1	24.4	7.5	-	-	-	-	-
40	5.6	31.2	24.7	6.5	-	-	7.6	-	-	-	-	-

Sulfite Waste Liquor

During six trips to the Ward Cove area, a total of 276 samples from the top 20-meter layer were collected and analyzed. These samples were collected at 15 stations distributed over an area greater than a square mile. Fifty percent of these samples had SWL concentrations greater than 44 ppm; 35 percent (from 15 stations) had concentrations greater than 100 ppm; 11 percent (from 8 stations) had concentrations greater than 500 ppm.

Concentrations of SWL in the top one-meter layer of water varied throughout the cove and adjacent waters from one study period to the next, and were higher in summer than in winter (Table 2). The highest concentrations of SWL, ranging from 175 ppm to over 2,000 ppm, were found on May 10, 1968 (Figure 7). SWL concentrations greater than 100 ppm were found at various times in a 1.4 square mile area throughout the study in Ward Cove and Tongass Narrows (Figure 8). Within this area, near the mill outfalls, SWL attained concentrations greater than 500 ppm in a 0.25 square mile zone.

High concentrations of SWL were again found during the July 3, 1968 sampling period, prior to a temporary mill shutdown. Four days after mill shutdown, the residual SWL concentrations were significantly reduced because of mixing between surface waters of the cove and the unpolluted waters of Tongass Narrows. At this time, the flow from Ward Creek was sufficient to move surface water away from the head of the cove. This movement was evidenced by a

TABLE 2

SULFITE WASTE LIQUOR CONCENTRATIONS (PPM)
WITH DEPTH (METERS) IN WARD COVE AND TONGASS NARROWS, 1968-1969.

		Station Numbers															
Depth	WC[a]	1	2	3	4	5	OF[b]	6	7	8	9	10	11	12	13	14	15
								May 10, 1968									
0	--	102	62	226	107	777	1080	2290	1110	791	1240	395	680	490	109	320	--
1	--	101	129	161	261	418	11060	2040	374	880	418	446	519	350	178	37	--
3	--	37	71	34	124	199	2710	809	424	468	127	91	272	277	54	15	--
4	--	9	35	--	--	--	212	--	--	--	--	--	--	--	--	--	--
5	--	--	--	--	40	44	--	175	49	148	50	24	23	37	43	19	--
9	--	--	--	--	--	436	--	10	--	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	--	<5	<5	36	--	--	--	--	--	--
								July 3, 1968									
0	--	--	361	339	455	571	18000	--	744	1030	854	322	394	193	30	208	--
1	--	--	214	214	303	415	11270	--	376	2070	260	311	231	208	30	221	--
3	--	--	44	34	31	42	90	--	39	27	26	54	27	145	32	81	--
7	--	--	15	8	<5	<5	11	--	<5	<5	<5	<5	<29	<5	<5	<5	--
								July 7, 1968									
0	--	--	--	--	52	59	--	--	--	--	--	--	--	--	--	--	--
1/2	--	33	23	44	28	68	--	--	40	34	28	23	27	28	--	--	--
1	--	--	--	--	--	26	--	--	--	--	--	--	--	--	--	--	--
1 1/2	--	11	8	21	9	11	--	--	13	11	10	23	17	23	--	--	--
2	--	--	--	--	16	7	--	--	--	--	--	--	--	--	--	--	--

TABLE 2 (Continued)

Depth	WR[a]	1	2	3	4	OF[b]	5	6	7	8	9	10	11	12	13	14	15
								October 8, 1968									
0	29	--	23	--	--	--	1073	528	--	689	--	--	556	--	--	--	<5
1	--	--	60	--	--	--	1111	244	--	142	--	--	80	--	--	--	7
3	--	--	32	--	--	--	112	61	--	28	--	--	20	--	--	--	--
5	--	--	28	--	--	--	34	16	--	14	--	--	8	--	--	--	--
7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	26	<5	--	<5	--	--	<5	--	--	--	<5
15	--	--	--	--	--	--	--	--	--	<5	--	--	<5	--	--	--	--
29	--	--	--	--	--	--	<5	--	--	--	--	--	--	--	--	--	--
								October 9, 1968									
0	--	--	--	--	--	--	--	--	--	--	--	--	--	91	19	35	--
1	--	--	--	--	--	--	--	--	--	--	--	--	--	33	8	46	--
3	--	--	--	--	--	--	--	--	--	--	--	--	--	6	9	21	--
5	--	--	--	--	--	--	--	--	--	--	--	--	--	<5	6	7	--
7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<5	--
10	--	--	--	--	--	--	--	--	--	--	--	--	--	<5	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	--	--	<5	--	--	--
29	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
								December 18, 1968									
0	20	--	21	--	--	--	273	658	--	483	--	--	208	--	9	35	25
1	--	--	45	--	--	--	203	483	--	162	--	--	104	84	12	--	20
3	--	--	15	--	--	--	--	--	--	--	--	--	--	--	--	--	--
5	--	--	14	--	--	--	14	10	--	<5	--	--	<5	9	<5	11	<5
8	--	--	9	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	7	<5	--	<5	--	--	<5	--	<5	<5	<5
13	--	--	--	--	--	--	--	--	--	--	--	--	--	<5	--	--	--
20	--	--	--	--	--	--	<5	<5	--	<5	--	--	<5	--	--	--	--

3/

TABLE 2 (Continued)

Depth	WC[a]	1	2	3	4	OF[b]	5	6	7	8	9	10	11	12	13	14	15
								April 13, 1969									
0	23	--	23	--	--	343	635	543	--	355	--	--	1272	766	9	--	86
1	--	--	99	--	--	--	269	336	--	34	--	--	159	185	8	--	76
3	--	--	24	--	--	--	--	--	--	--	--	--	--	--	--	--	--
5	--	--	9	--	--	--	42	18	--	32	--	--	8	<5	<5	--	8
10	--	--	<5	--	--	--	8	8	--	<5	--	--	<5	<5	--	--	<5
20	--	--	--	--	--	--	<5	<5	--	<5	--	--	<5	<5	--	--	--
								May 13, 1969									
0	--	--	79	--	--	559	867	812	--	1097	--	--	246	1393	943	226	264
1	--	--	76	--	--	--	184	--	--	272	--	--	206	--	--	--	--
5	--	--	--	--	--	--	49	--	--	50	--	--	25	--	--	--	--
6	--	--	44	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	12	--	--	--	--	--	--	--	--	--	--

a Ward Cove
b Outfall

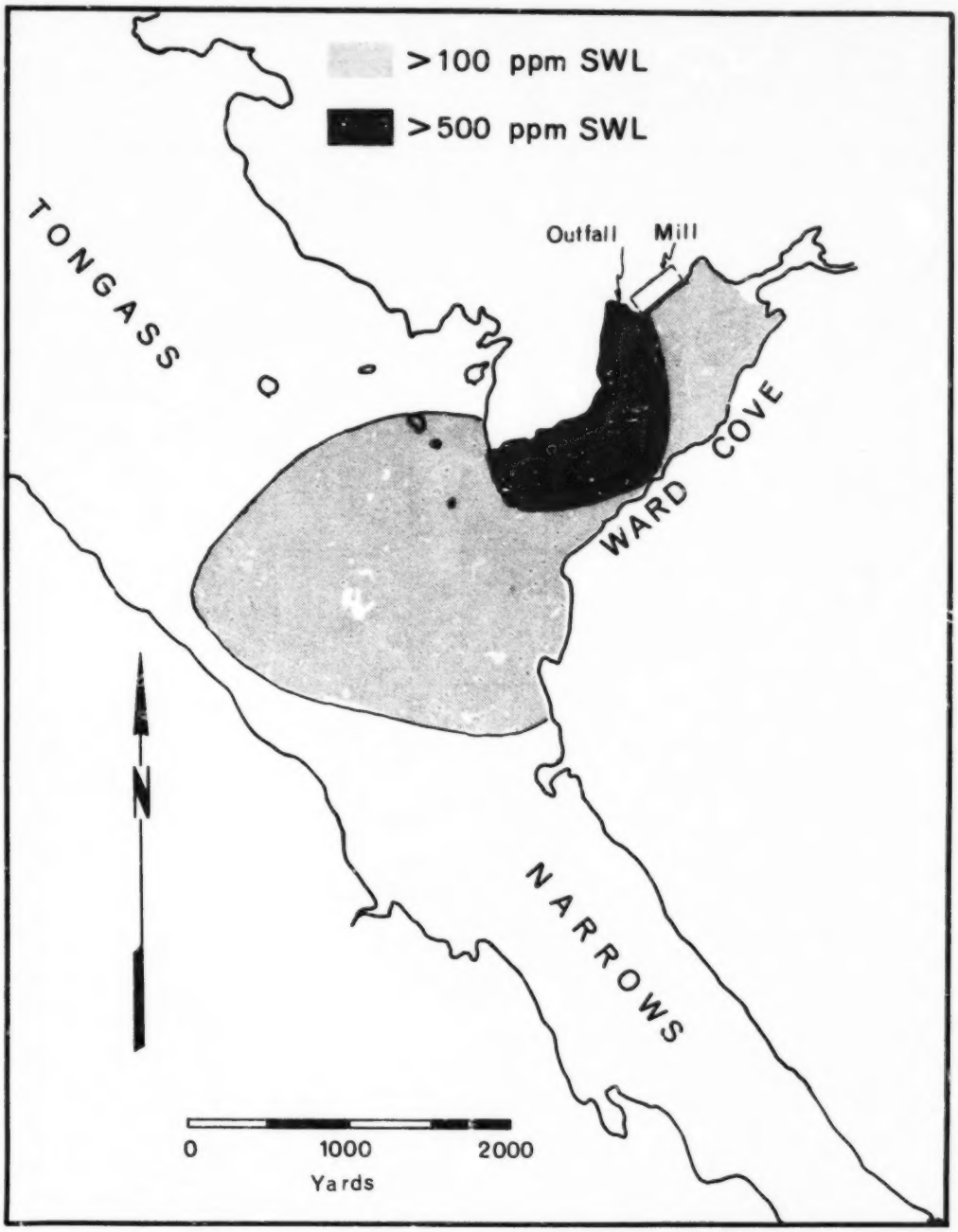

FIGURE 7. Zones in Ward Cove and Tongass Narrows where high SWL concentrations can be expected at various times throughout the year.

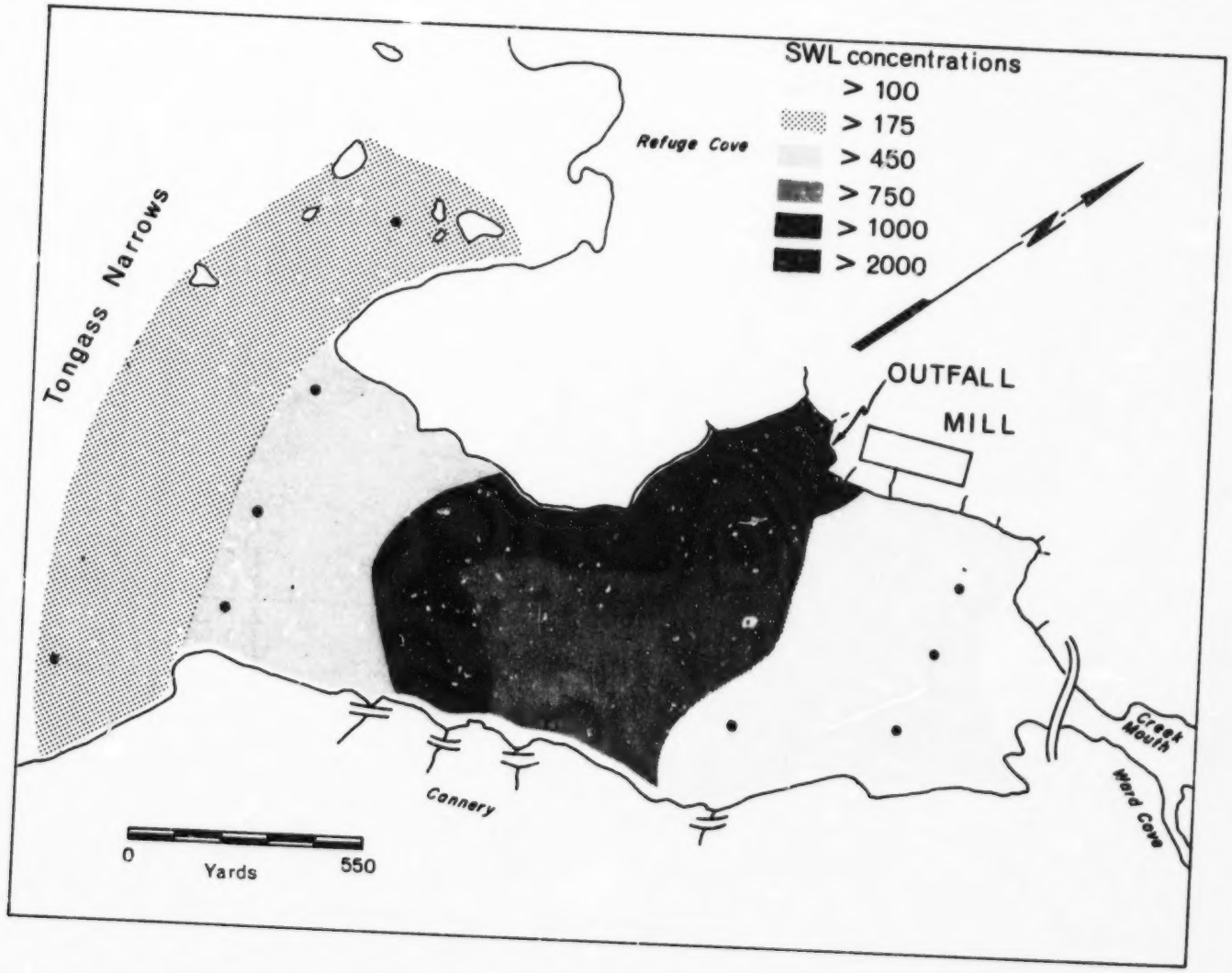

FIGURE 8. Distribution of high concentrations of SWL in Ward Cove, May 10, 1968.

reduction of about 85 percent in SWL concentrations at the head of the cove.

Vertically, SWL was distributed throughout the entire water column near the outfall and in the shallow waters near the head of the cove. SWL generally was found in measurable concentrations down to the 5-to-10-meter depth within the cove (Figure 9); beyond the cove it was seldom found below the 5-meter depth.

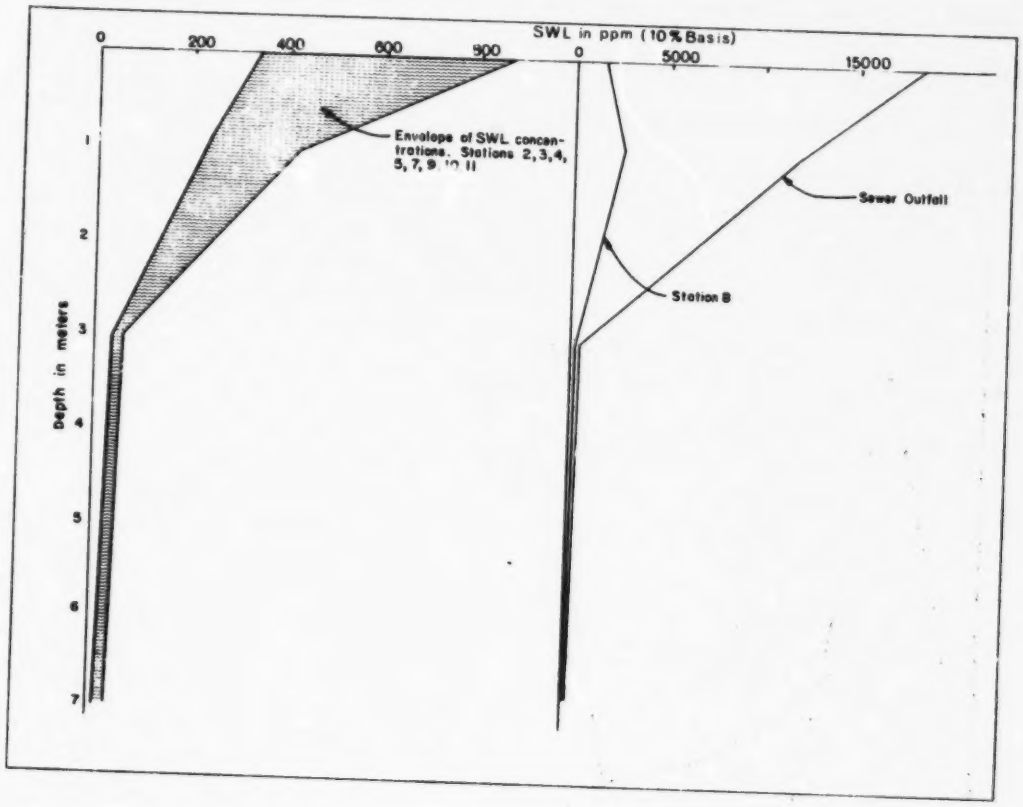

FIGURE 9. Depth distribution of SWL in Ward Cove, July 3, 1968.

Yearly variation in SWL was found throughout the study area. Stations 8 and 11, which are 0.4 and 0.8 miles, respectively, from the main sewer outfall, typically reflected such variation between May 1968 and May 1969 (Figure 10). SWL concentrations were highest during the spring, summer, and early fall, and lowest during the winter. This is to be expected when the differences in water column stability and storm activity during these seasons is considered. Thus, during seasons when stratification of waters occurred, the rate of dispersal of SWL from Ward Cove was minimal and SWL concentrations were high. During the winter when lateral water movements (horizontal mixing) caused by storms were highest, the SWL concentrations were lowest.

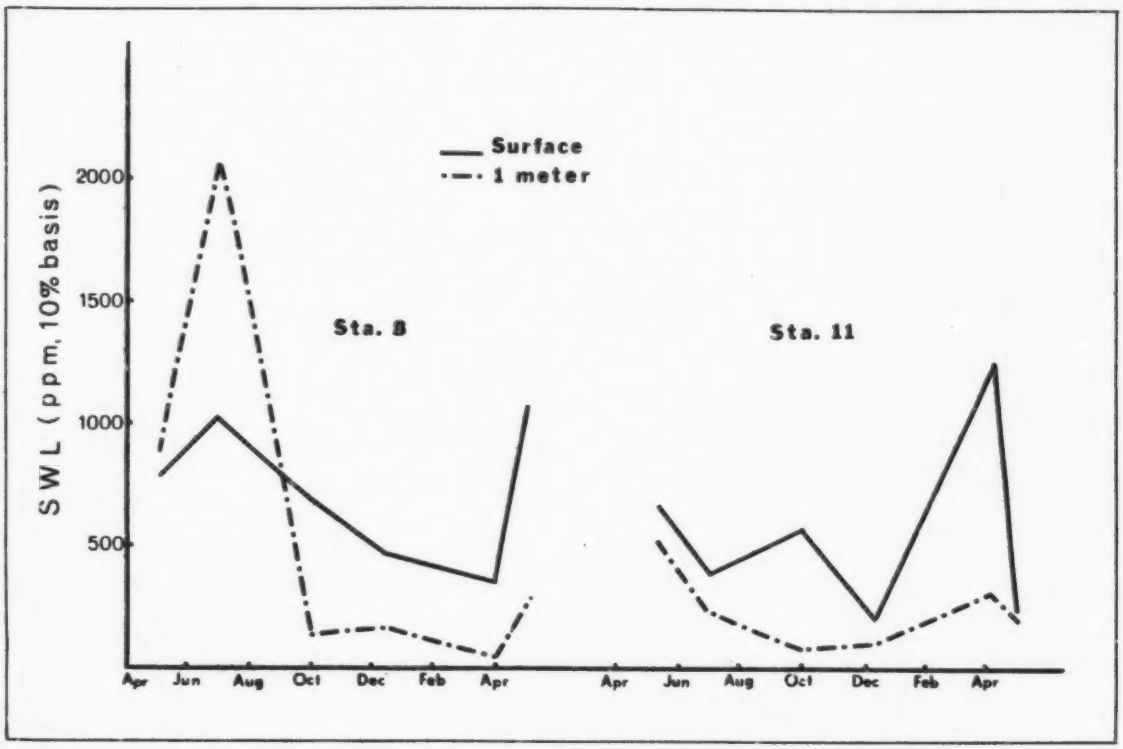

FIGURE 10. SWL concentrations at Stations 8 and 11 in Ward Cove, May, 1968 through May, 1969.

Additionally, the correlation in the maximum and minima in SWL concentrations between Stations 8 and 11 (i.e., a maximum at one station generally corresponds to a minimum or low SWL value at the other station) strongly suggests that mill wastes accumulate during the slack portion of the tide. The SWL moves out of the cove in fronts or slugs of high concentration during each ebb tide.

Tongass Narrows water receives the SWL concentration from Ward Cove through the exchange process resulting from the tidal fluctuation and eddy currents. This SWL is then carried away from the Cove mouth and dispersed in the more turbulent, deeper waters of Tongass Narrows.

The light transmitting properties of the surface waters in Ward Cove and the adjacent waters of Tongass Narrows was significantly decreased (Table 3). On July 3, 1968, mill wastes reduced light intensity in the vicinity of Station 6 by 43 percent. At the mouth of the cove, it was reduced 14 to 25 percent (stations 10,11, and 12). The greatest reduction in light intensity occurred within the top 7-meter layer. A significant increase in transmissivity was observed on July 5 and 6, the first and second days after the mill stopped discharging wastes. At greater depths, where concentrations of SWL were low, the transmissivity was quite high.

Dissolved Oxygen

Dissolved oxygen in the surface waters of Ward Cove frequently was reduced to less than 6 mg/l, the minimum allowed by the water

quality standards. Of 413 dissolved oxygen measurements at 15 stations, 37 percent (from 14 stations) were below the minimum of 6 mg/1. Additionally, of 336 measurements made in the upper 29-meter water layer, 35 percent (from 14 stations) were below the standard (Appendix, Table 2A).

TABLE 3.
TRANSMISSIVITY READINGS (PERCENTAGE) WITH DEPTH (METERS) IN WARD COVE AND TONGASS NARROWS (READINGS TAKEN WITH 10 CM TRANSMISSOMETER), JULY 1968.

Depth	Stations 1	2	3	4	5	6	7	8	9	10	11	12	13	14
						July 3, 1968								
0		76	65	70	67	45	71	68	61	69	63	74	88	80
1		78	70	74	69	62	72	66	66	70	67	74	88	80
3		93	84	83	75	79	89	92	89	84	89	78	89	83
7		94	90	90	95	80	100	98	95	90	87	89	95	97
11		-	93	93	99	88	100	98	97	92	96	91	97	98
						July 5, 1968								
0		97	84	79	82	81	85	82	87	90	90	89	99	94
1		100	89	89	82	85	92	85	90	95	94	95	98	94
3		100	96	95	92	93	97	94	93	95	96	97	98	95
7		100	97	97	94	93	99	95	95	96	96	97	99	98
11		-	99	97	95	92	99	96	95	98	97	-	-	98
						July 6, 1968								
0	61	88	92	80	89	87	92	95	92	96	92	98	95	98
1	87	97	97	98	94	90	95	97	97	98	97	98	95	98
3	97	98	100	100	99	96	98	98	98	99	100	100	100	100
7	99	100	-	100	100	95	100	100	100	100	100	100	100	100
11	-	-	-	-	100	97	100	100	100	100	-	-	-	-

In the year prior to mill operation, Ward Cove had high dissolved oxygen values ranging from 7 to 12 mg/1 (Figure 11). During this year the dissolved oxygen reached a maximum of 12 mg/1 or 122 percent saturation during the spring. This is the period when one would expect greatest phytoplankton activity. Minimum values near 7 mg/1 occurred during fall and winter. The data collected in the 1968-1969 study period (Figure 12) suggest almost a reversal of this situation, with a dissolved oxygen maximum occurring only during spring and a minimum occuring during summer.

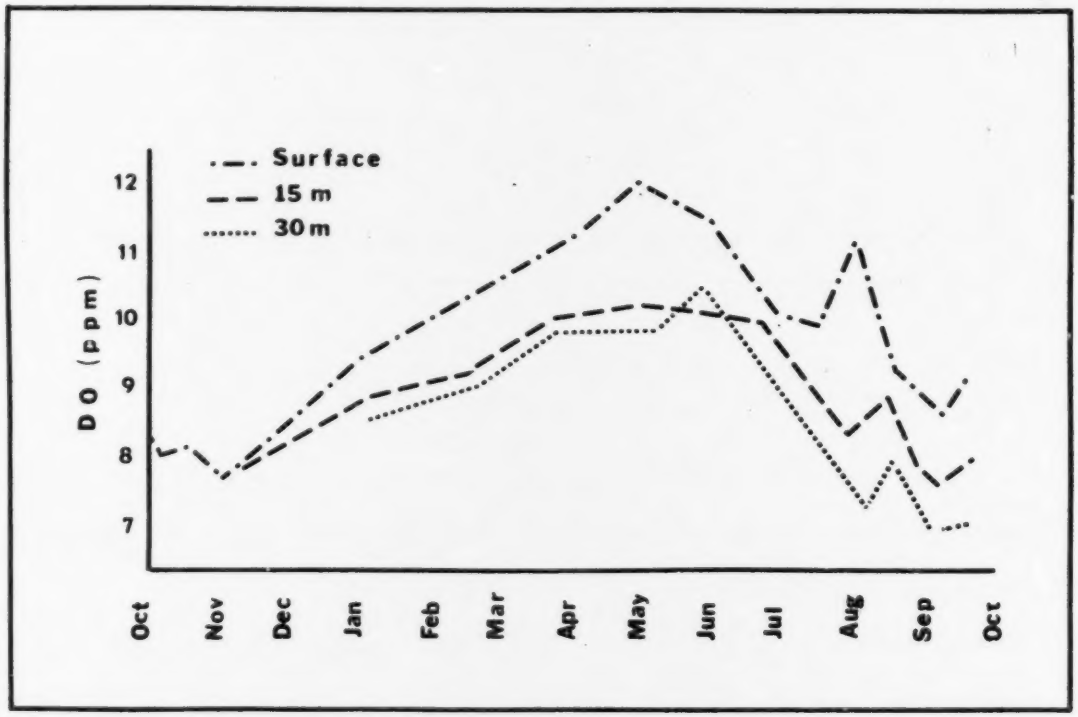

FIGURE 11. Averaged dissolved oxygen concentrations in Ward Cove prior to construction of pulp mill, October 1951 through September 1952. (Reference No. 3)

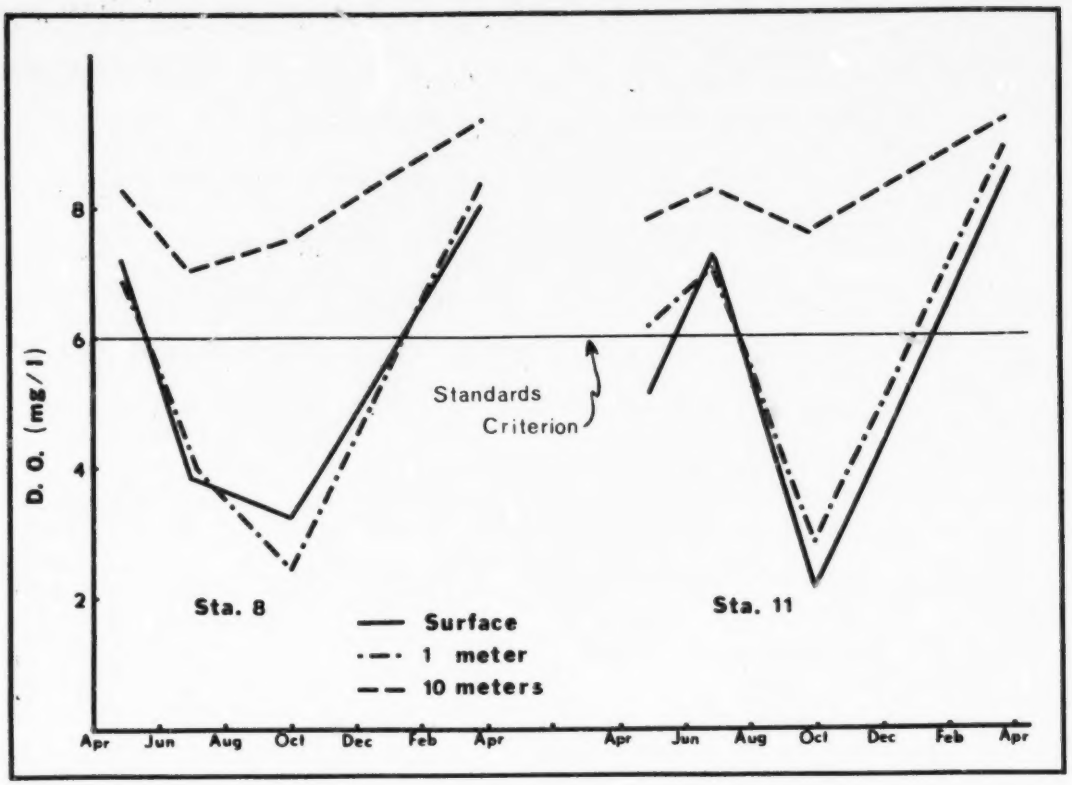

FIGURE 12. Dissolved oxygen concentrations at Stations 8 and 11 in Ward Cove, May 1968 through May 1969.

Spring maxima in dissolved oxygen in the surface waters of Ward Cove were indicated during May 1968 and April 1969. Dissolved oxygen values for both periods showed a reduction from maximum saturation by 38 to 73 percent in May 1968 and by 31 to 42 percent in April 1969. Preceding mill operation, super-saturation of these waters amounted to 122 percent in a comparable season.

The low dissolved oxygen levels in the late spring and summer are consistent with the reduction of phytoplankton activity expected when SWL concentrations reach the high levels measured during these sampling periods. Oxygen-producing phytoplankton in the upper water layers are adversely affected by the toxicity and the presence of a log cover which decreases available light. Those deeper in the water column will be affected because of the reduction in transmissivity and, as a consequence, the reduced energy for phytosynthesis. The low dissolved oxygen observed in surface waters in October, when SWL concentrations were relatively low, probably was the result of waste loading, decreased phytoplankton activity, and intrusion of oceanic bottom waters that characteristically are low in dissolved oxygen.

Dissolved oxygen in the surface waters of Ward Cove generally increased about 5 mg/l on July 8, 1968; 5 days after the mill was temporarily shut down (Figure 13). On July 3, 1968, prior to this shutdown, the dissolved oxygen in surface waters was extremely low, varying from 1.8 to 4.8 mg/l. Regardless of combinations of data used to graphically compare dissolved oxygen on these two dates the significance of the data is not altered. The mill wastes were responsible for significantly reducing dissolved oxygen below the standard of 6 mg/l in at least the upper 29 meters of most waters in Ward Cove.

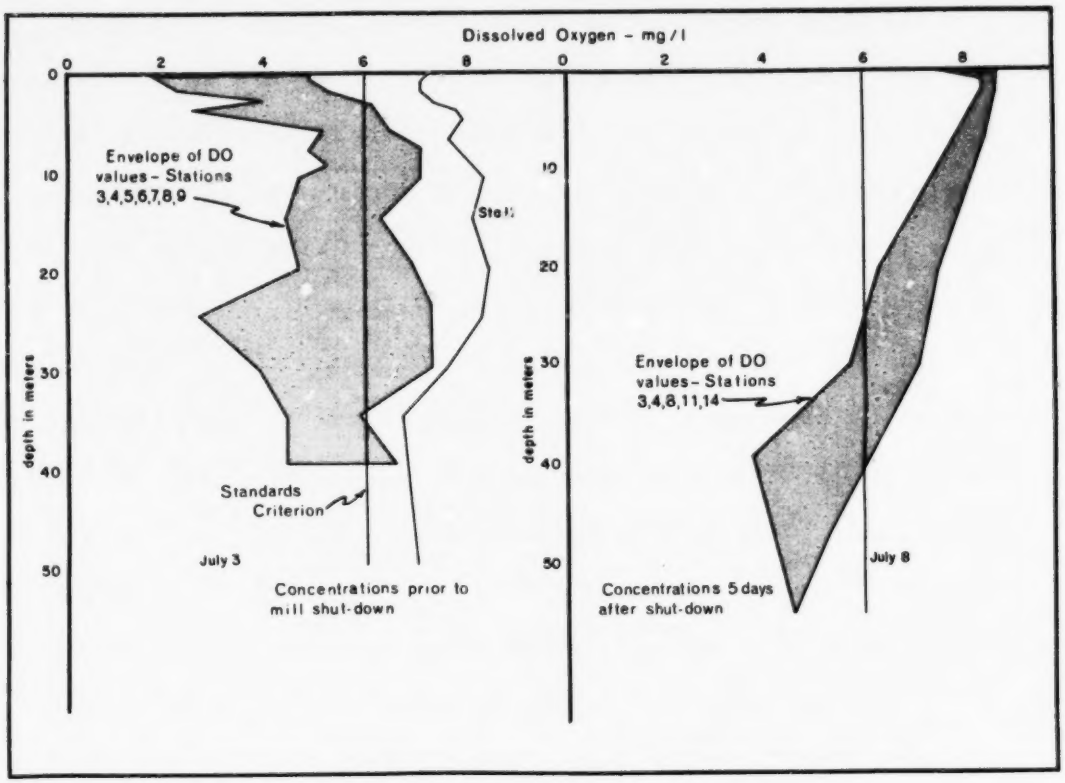

FIGURE 13. Depth distribution of dissolved oxygen concentrations in Ward Cove and Tongass Narrows on July 3 and July 8, 1968.

Biological

Benthic Plants and Animals

Unpublished information from the State of Alaska reveal that many clean-water bottom organisms such as mussels, snails, brown algae, crabs, starfish, urchins, and green algae thrived in great abundance in Ward Cove prior to completion of the pulp mill. Such organisms, unlike fish, reflect water quality over a long period of time, usually a year, because they have limited mobility.

During the 1968-1969 study, samples of bottom materials from Stations 2, 5, 8, 9, 10, 11, 13, and 14 (Figure 5) did not contain organisms such as starfish, crabs, and urchins. Only a few microscopic animals and remnants of other organisms, for example fish scales and vertebrae, worm cases, mollusk shells, sponges, and urchin spines were found at these sites (Appendix, Table 4A). The reduction of aquatic life, and the prevalence of black, foul-smelling sludge that contained wood chips and pulp fibers attest to the severely polluted condition of Ward Cove. Fiber-containing sludge from benthic reaches near Station 6 and the mill outfalls frequently was noted on surface waters (Figure 14).

The pollution in Ward Cove also was evident in intertidal reaches that previously supported a great variety of organisms such as several kinds of attached algae, snails, starfish, and blue mussels. Investigations during the 1968-1969 study showed that many kinds of such plants and animals no longer lived in the intertidal reaches. Blue mussels, Mytilus edulis, sampled at ten sites in the intertidal zone of Ward Cove and Tongass Narrows (Figure 15), were abundant in Tongass Narrows but significantly reduced in numbers within Ward Cove (Table 4 and Appendix, Table 5A).

TABLE 4.

Total Numbers of Blue Mussels, Mytilus edulis, Collected Per 30-Minute Sampling Effort at 10 Intertidal Stations in Ward Cove and Tongass Narrows, May and July, 1968.

Sampling Date	1	2	3	4	5	6	7	8	9	10
May 1968	843	661	434	435	291	489	58	159	418	550
July 1968	1978	1461	685	906	602	551	53	236	618	1251

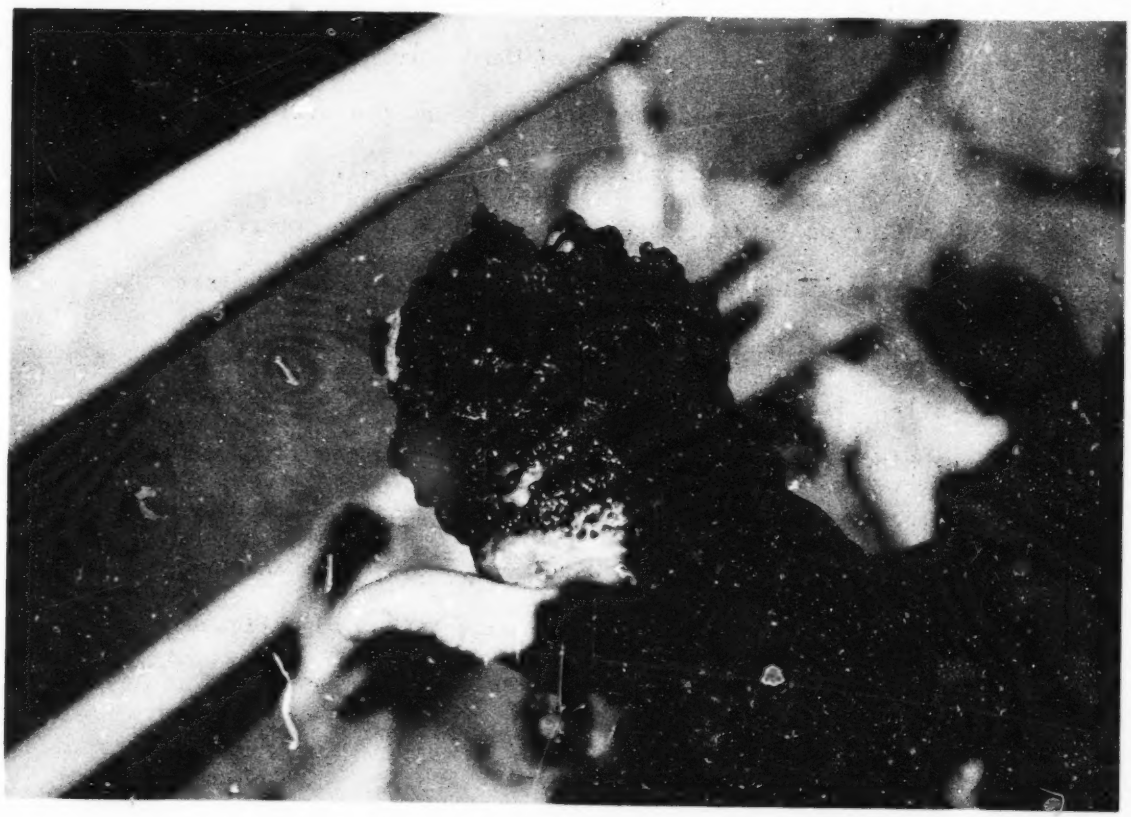

FIGURE 14. Decomposing bottom material which has risen to the surface near the main sewer outfall.

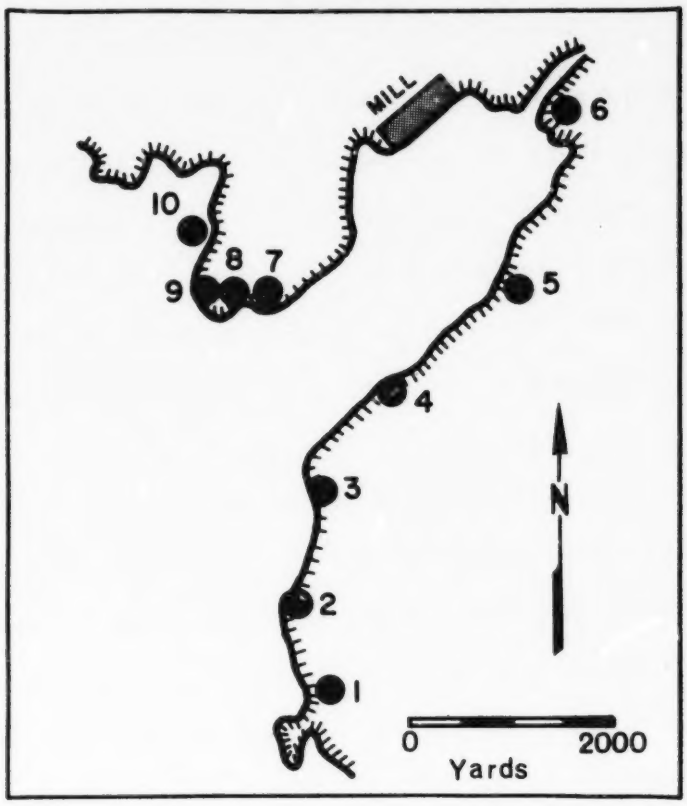

FIGURE 15. Location of intertidal stations in Ward Cove and Tongass Narrows where Mytilus edulis were collected.

In May 1968, less that 500 of these organisms per sample were found at Stations 3 through 9. Less than 100 were found in either May or July 1968 at Station 7 near the mouth of the cove. None of these hardy semi-pollution tolerant animals were found nearer the mill outfalls.

Plankton

Sampling for microscopic plants and animals floating in the water (Appendix, Table 6A) was done in a superficial manner only, and was inadequate to establish patterns of plankton numbers and diversity associated with oxygen production and pollutional effects of the SWL. Nevertheless, studies in other waters reveal such plankton information, and are generally applicable to Ward Cove (8 and 9).

High dissolved oxygen concentrations in estuarine and near-shore marine waters are typically the consequence of increased algae populations (attached and/or planktonic). These exhibit seasonal patterns of abundance that are associated with seasonal changes in water column mixing, nutrients, temperature, and daylight. Characteristically, marine waters are nutrient-rich in early spring as a result of winter mixing. This, coupled with increased water column stability, increased temperature, and lengthening days, creates favorable conditions for phytoplankton activity and a bloom begins. The bloom is evidenced by an increase in phytoplankton and dissolved oxygen and may also be followed by an increase in zooplankton. Often the water becomes supersaturated with dissolved oxygen. The spring bloom of attached algae in shallow waters usually is most noticeable in late April or early May. Shortly thereafter, it begins to subside because nutrients are depleted. At the same time the algae becomes less abundant and the dissolved oxygen decreases to lower levels that persist throughout the remaining summer.

In late August or early September, water stability established during the summer begins to decline, mixing follows, and nutrients stimulate another phytoplankton bloom and an associated increase in dissolved oxygen. This bloom is often short-lived because temperature and lengths of days are decreased to wintertime levels. This annual phytoplankton cycle is inferred by plotting dissolved oxygen concentrations obtained throughout a period of one or more years, as was done with dissolved oxygen data from Ward Cove prior to operations of the pulp mill (Figure 11). It is apparent that dissolved oxygen was sufficiently abundant to result in supersaturation (the cyclic pattern of phytoplankton abundance with blooms in May and August is implied).

The 1968-1969 data showing reduced oxygen content at Stations 8 and 11 similarly imply the toxic effect of SWL on phytoplankton (Figure 12). SWL reportedly inhibits phytoplankton activity at concentrations exceeding 50 ppm (8). Additionally, SWL reduced the amount of light entering Ward Cove waters. It is axiomatic that the photosynthetic process of phytoplankton and attached algae is decreased if light is decreased, and that oxygen production therefore will be reduced. Biochemical oxygen demand of the SWL and associated wastes discharged to Ward Cove also contribute to the decrease of dissolved oxygen concentration.

Fish and Other Associated Animals

Extensive studies in the Puget Sound area (8) have shown that SWL concentrations above 10 ppm are detrimental to many forms of biological life, particularly larval stages which are found in the upper 10 meters of the water column.

Although not derived in the 1968-1969 study at Ward Cove, toxicity data from other studies reveal that SWL and associated wastes are toxic to salmon and salmon-food organisms. In Puget Sound (8), survival and well-being of juvenile salmon were impaired when the following criteria were not met:

SWL - less than 1,000 ppm

Total sulfides - no detectable amount

Dissolved oxygen - greater than 5 mg/l

pH - greater than 6.5

Ammonia Nitrogen - 0.2 mg/l

The first three of these criteria frequently are not met in Ward Cove. In the vicinity of the mill outfalls and in extensive benthic reaches of the cove, sulfides were so apparent that they were detected readily by their strong hydrogen sulfide odor. A second study (9) shows that calcium-base SWL is toxic or inhibitory to certain salmon-food and other associated organisms at concentrations exceeding 50 ppm. This study concluded that "to be entirely on the safe side of the toxicity range, concentrations of sulfite waste liquor solids should not exceed 50 ppm" in waters where salmon

are expected to feed. A concentration of 50 ppm of SWL was exceeded, at times, over nearly the entire study area in Ward Cove and Tongass Narrows.

It should be pointed out that while SWL concentrations less than 1,000 ppm can be tolerated by juvenile salmon, they would be toxic or otherwise adverse to salmon-food and other associated organisms. Thus, 50 ppm of SWL, or less, appears to be an upper limit necessary for the sustained survival and well-being of salmon food; whereas 10 ppm appears to be the upper threshold for other aquatic organisms, particularly during larval stages (8).

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TABLE 1A

Salinity (o/oo) With Depth (Meters) in Ward Cove and Tongass Narrows, 1968-1969.

Depth	Station Numbers											
	1	2	3	4	5	6	7	8	9	10	11	12
						May 10, 1968						
0	24.4	24.8	26.0	26.5	25.8	-	26.1	-	26.8	-	-	-
1	28.3	26.1	26.6	27.1	26.4	-	27.8	-	27.7	-	-	-
3	28.2	26.8	28.2	28.4	28.3	-	28.3	-	28.4	-	-	-
5	-	28.2	28.8	28.7	28.6	-	28.9	-	28.5	-	-	-
7	-	28.6	29.4	29.2	29.1	-	-	-	29.2	-	-	-
11	-	29.3	29.9	29.7	29.9	-	30.0	-	30.1	-	-	-
13	-	29.3	-	-	-	-	30.0	-	30.1	-	-	-
16	-	-	-	29.7	29.8	-	30.4	-	30.2	-	-	-
20	-	-	-	29.9	30.3	-	30.4	-	30.3	-	-	-
25	-	-	-	30.2	-	-	30.6	-	30.6	-	-	-
30	-	-	-	30.6	-	-	30.6	-	30.7	-	-	-
40	-	-	-	-	-	-	30.9	-	30.9	-	-	-
44	-	-	-	-	-	-	-	-	30.9	-	-	-
						May 15, 1968						
0	8.2	25.1	22.5	24.1	24.3	22.6	26.5	27.2	26.4	27.5	24.1	25.1
1	25.7	26.4	26.9	27.8	27.8	27.0	27.8	29.3	28.4	29.1	27.9	28.7
3	28.3	29.8	30.0	30.0	30.2	29.8	29.8	30.1	30.1	30.0	30.3	29.8
5	-	30.1	30.2	30.3	30.4	30.1	30.0	30.3	30.4	30.2	30.4	30.1
7	-	-	30.3	30.5	30.6	30.2	30.2	30.5	30.4	30.2	30.5	30.1
11	-	-	30.5	30.4	30.8	30.4	30.3	30.5	30.6	30.5	30.6	30.4
15	-	-	30.2	30.7	31.0	30.4	30.5	30.6	30.6	30.6	30.7	30.5
20	-	-	-	30.8	31.1	-	30.5	30.8	30.8	30.8	30.8	30.6
25	-	-	-	31.0	31.2	-	30.7	30.9	31.0	30.9	30.9	30.7
30	-	-	-	31.0	31.0	-	30.9	31.1	31.1	31.0	31.2	31.0
35	-	-	-	31.0	-	-	30.9	31.1	31.2	31.1	31.2	30.6
40	-	-	-	30.9	-	-	31.0	31.4	31.3	31.2	31.2	30.7

TABLE 1A (Continued)

Salinity (o/oo) With Depth (Meters) in Ward Cove and Tongass Narrows, 1968-1969.

	Station Numbers									
Depth	3	4	5	6	7	8	9	10	11	12
					July 3, 1968					
0	22.2	24.0	23.8	27.0	24.1	24.6	24.8	26.4	24.4	25.6
1	24.3	24.1	23.9	24.3	24.5	25.0	24.9	26.4	26.4	25.9
2	24.8	25.3	25.3	24.6	25.5	25.8	27.8	26.4	26.4	26.1
3	25.6	25.9	25.9	25.3	25.7	26.0	25.8	26.4	26.4	26.2
4	26.0	26.0	25.9	25.8	26.1	26.1	26.3	26.4	26.8	26.8
5	25.9	26.2	26.1	26.3	26.1	26.2	26.5	26.5	26.7	27.3
7	26.1	26.2	26.7	26.6	27.0	27.3	27.2	27.7	27.0	27.9
11	27.8	27.9	28.4	28.3	28.2	28.5	28.8	28.7	28.4	28.8
15	28.4	28.5	29.2	28.9	29.0	29.0	29.2	29.2	29.6	29.2
20	-	29.2	29.5	29.6	29.6	29.4	29.7	29.8	30.0	29.6
25	-	29.4	29.7	28.6	29.6	29.9	30.1	30.1	30.5	30.2
30	-	29.7	28.2	-	30.1	30.2	30.2	30.4	30.8	-
35	-	29.7	-	-	30.5	30.4	30.8	30.8	31.1	-
40	-	-	-	-	30.8	30.8	30.9	31.1	31.5	-
50	-	-	-	-	-	-	-	-	31.7	-

Depth	2	5	6	OF*	8	11	12	13	14	15
					April 13, 1969					
0	3.3	20.4	16.4	*29.0	14.9	26.0	29.4	30.7	-	30.5
1	30.1	30.1	30.0	-	30.3	30.3	30.6	30.8	-	30.7
3	30.7	-	-	-	-	-	-	-	-	-
5	31.1	31.0	30.8	-	30.9	31.3	31.4	31.3	-	31.2
10	31.2	31.1	31.2	-	31.6	31.7	31.4	-	-	31.2
20	-	31.8	31.6	-	31.6	31.6	31.7	-	-	-

* Outfall

TABLE 1A

Salinity (o/oo) With Depth (Meters) in Ward Cove and Tongass Narrows, 1968-1969.

Depth	Station Numbers											
	1	2	3	4	5	6	7	8	9	10	11	12
						May 10, 1968						
0	24.4	24.8	26.0	26.5	25.8	-	26.1	-	26.8	-	-	-
1	28.3	26.1	26.6	27.1	26.4	-	27.8	-	27.7	-	-	-
3	28.2	26.8	28.2	28.4	28.3	-	28.3	-	28.4	-	-	-
5	-	28.2	28.8	28.7	28.6	-	28.9	-	28.5	-	-	-
7	-	28.6	29.4	29.2	29.1	-	-	-	29.2	-	-	-
11	-	29.3	29.9	29.7	29.9	-	30.0	-	30.1	-	-	-
13	-	29.3	-	-	-	-	30.0	-	30.1	-	-	-
16	-	-	-	29.7	29.8	-	30.4	-	30.2	-	-	-
20	-	-	-	29.9	30.3	-	30.4	-	30.3	-	-	-
25	-	-	-	30.2	-	-	30.6	-	30.6	-	-	-
30	-	-	-	30.6	-	-	30.6	-	30.7	-	-	-
40	-	-	-	-	-	-	30.9	-	30.9	-	-	-
44	-	-	-	-	-	-	-	-	30.9	-	-	-
						May 15, 1968						
0	8.2	25.1	22.5	24.1	24.3	22.6	26.5	27.2	26.4	27.5	24.1	25.1
1	25.7	26.4	26.9	27.8	27.8	27.0	27.8	29.3	28.4	29.1	27.9	28.7
3	28.3	29.8	30.0	30.0	30.2	29.8	29.8	30.1	30.1	30.0	30.3	29.8
5	-	30.1	30.2	30.3	30.4	30.1	30.0	30.3	30.4	30.2	30.4	30.1
7	-	-	30.3	30.5	30.6	30.2	30.2	30.5	30.4	30.2	30.5	30.1
11	-	-	30.5	30.4	30.8	30.4	30.3	30.5	30.6	30.5	30.6	30.4
15	-	-	30.2	30.7	31.0	30.4	30.5	30.6	30.6	30.6	30.7	30.5
20	-	-	-	30.8	31.1	-	30.5	30.8	30.8	30.8	30.8	30.6
25	-	-	-	31.0	31.2	-	30.7	30.9	31.0	30.9	30.9	30.7
30	-	-	-	31.0	31.0	-	30.9	31.1	31.1	31.0	31.2	31.0
35	-	-	-	31.0	-	-	30.9	31.1	31.2	31.1	31.2	30.6
40	-	-	-	30.9	-	-	31.0	31.4	31.3	31.2	31.2	30.7

TABLE 1A (Continued)

Salinity (o/oo) With Depth (Meters) in Ward Cove and Tongass Narrows, 1968-1969.

	Station Numbers									
Depth	2	5	6	OF*	8	11	12	13	14	15
					May 13, 1969					
0	10.8	21.7	19.9	*27.4	23.3	30.8	26.1	22.7	30.2	28.4
1	29.4	29.3	-	-	29.3	30.8	-	-	-	-
5	30.4	30.6	-	-	30.5	30.6	-	-	-	-
10	-	30.9	-	-	-	-	-	-	-	-

* Outfall

TABLE 2A

Temperature (°C) With Depth (Meters) in Ward Cove and Tongass Narrows, 1968-1969.

Depth	Station Numbers											
	1	2	3	4	5	6	7	8	9	10	11	12
					May 10, 1968							
0	10.2	12.7	10.4	10.2	10.3	-	9.7	-	10.9	-	-	-
1	7.6	9.8	9.9	9.4	10.1	-	8.0	-	8.3	-	-	-
3	7.7	7.8	8.1	7.8	8.2	-	7.6	-	7.9	-	-	-
5	-	6.8	7.2	6.8	7.4	-	6.9	-	7.5	-	-	-
7	-	6.4	6.2	6.3	6.7	-	-	-	6.9	-	-	-
11	-	5.9	6.2	5.8	6.1	-	6.0	-	5.8	-	-	-
13	-	5.9	-	-	-	-	5.7	-	5.8	-	-	-
16	-	-	-	5.9	5.9	-	5.5	-	5.6	-	-	-
	-	-	-	5.7	5.9	-	5.5	-	5.5	-	-	-
25	-	-	-	5.6	-	-	5.4	-	5.6	-	-	-
30	-	-	-	5.6	-	-	5.5	-	5.4	-	-	-
40	-	-	-	-	-	-	5.4	-	5.4	-	-	-
44	-	-	-	-	-	-	-	-	5.4	-	-	-
					May 15, 1968							
0	7.6	8.9	8.2	9.1	9.4	10.3	8.8	8.2	9.2	8.4	8.7	8.6
1	8.0	8.7	8.4	8.7	8.9	8.6	8.2	7.4	8.5	7.7	8.4	7.9
3	7.4	7.4	7.0	7.2	7.5	7.3	7.4	7.3	7.1	7.0	7.2	7.3
5	-	6.8	6.7	6.6	6.9	6.6	7.1	6.7	6.6	6.9	6.6	6.8
7	-	-	6.7	6.7	6.6	6.6	6.7	6.5	6.5	6.6	6.5	6.8
11	-	-	6.2	6.4	6.2	6.3	6.4	6.2	6.4	6.2	6.3	6.2
15	-	-	6.3	6.0	5.9	5.9	6.0	6.0	6.2	6.1	6.1	6.1
20	-	-	-	5.8	5.8	-	6.0	5.9	6.0	5.8	5.9	5.8
25	-	-	-	5.8	5.7	-	5.8	5.7	5.7	5.6	5.7	5.6
30	-	-	-	5.6	5.7	-	5.7	5.6	5.6	5.6	5.7	5.6
35	-	-	-	5.8	-	-	5.6	5.6	5.6	5.6	5.6	5.7
40	-	-	-	5.7	-	-	5.7	5.5	5.6	5.6	5.6	5.7

TABLE 2A (Continued)

Continued. Temperature (°C) With Depth (Meters) in Ward Cove and Tongass Narrows, 1968-1969.

Depth	Station Numbers											
	1	2	3	4	5	6	7	8	9	10	11	12
					July 3, 1968							
0	-	-	17.2	16.7	16.9	17.1	15.8	15.4	15.9	14.4	14.8	16.0
1	-	-	15.7	16.5	16.5	15.9	14.9	15.1	15.0	14.4	14.7	15.9
2	-	-	15.0	15.2	15.0	15.6	14.0	14.7	15.1	14.3	14.7	15.3
3	-	-	14.7	14.8	14.7	14.7	14.1	14.8	15.5	14.3	14.6	15.2
4	-	-	14.5	14.4	14.4	13.6	13.7	14.4	13.6	13.9	13.5	13.7
5	-	-	13.9	14.2	13.3	13.3	13.4	13.3	13.1	13.1	13.6	13.1
7	-	-	13.2	13.1	12.6	12.4	12.1	11.7	11.8	11.4	12.3	11.8
11	-	-	10.8	11.2	10.3	10.6	10.4	10.1	10.2	10.2	10.8	10.6
15	-	-	10.2	9.9	9.4	9.7	9.6	9.5	9.5	9.4	10.0	10.2
20	-	-	-	9.2	8.6	8.7	8.8	8.9	8.7	8.6	8.6	9.2
25	-	-	-	8.4	8.2	9.0	8.1	8.1	8.1	8.0	8.1	8.5
30	-	-	-	8.4	8.6	-	7.9	7.4	8.2	7.5	7.4	-
35	-	-	-	7.2	-	-	7.0	7.0	6.8	6.8	6.9	-
40	-	-	-	-	-	-	6.6	6.4	6.7	6.5	6.5	-
50	-	-	-	-	-	-	-	-	-	-	6.2	-

Depth	2	5	6	8	11	12	13	14	15
					April 13, 1969				
0	4.3	6.8	8.0	8.9	7.9	6.8	-	-	5.9
1	5.5	6.0	6.0	5.8	6.0	5.8	-	-	5.9
2	5.4	5.8	5.8	5.6	5.5	5.6	-	-	6.0
3	5.4	5.7	5.6	5.5	5.3	5.4	-	-	5.7
5	5.3	5.7	5.3	5.5	5.2	5.2	-	-	5.2
7	5.3	5.6	5.3	5.4	5.2	5.1	-	-	5.2
10	5.3	5.4	5.2	5.3	-	5.1	-	-	5.2
14	5.2	5.3	5.1	5.2	-	5.1	-	-	5.1

TABLE 3A

Dissolved Oxygen Concentrations (mg/l) With Depth (Meters) in Ward Cove and Tongass Narrows, 1968-1969.

Depth	Station Numbers										
	1	2	3	4	4*	5	6	7	8	9	10
	May 10, 1968										
0	1.7	3.5	4.4	5.6	5.4	6.4	-	6.9	-	6.1	-
1	3.8	4.6	4.6	5.9	5.9	5.9	-	8.3	-	8.5	-
3	3.8	5.6	6.2	7.2	7.3	6.7	-	8.6	-	8.8	-
5	-	6.0	7.0	7.0	7.3	6.8	-	8.3	-	8.6	-
7	-	5.7	7.0	7.0	8.0	7.0	-	-	-	8.8	-
11	-	5.7	6.4	7.2	7.8	7.0	-	-	-	-	-
13	-	6.2	-	-	-	-	-	-	-	-	-
15	-	-	-	-	7.3	6.4	-	8.0	-	-	-
16	-	-	-	7.0	-	-	-	-	-	-	-
20	-	-	-	4.3	6.7	6.4	-	-	-	-	-
21	-	-	-	3.3	-	5.6	-	-	-	-	-
22	-	-	-	3.0	-	-	-	-	-	-	-
25	-	-	-	1.6	6.0	-	-	6.6	-	-	-
26	-	-	-	0.9	-	-	-	-	-	-	-
30	-	-	-	0.6	4.8	-	-	5.2	-	-	-
32	-	-	-	0.0	3.8	-	-	-	-	-	-
35	-	-	-	-	-	-	-	7.4	-	-	-
40	-	-	-	-	-	-	-	7.4	-	-	-

* These two sets of data for Station 4 show the variation over a 1-1/4 hour period.

TABLE 3A (Continued)

Dissolved Oxygen Concentrations (mg/l) With Depth (Meters) in Ward Cove and Tongass Narrows, 1968-1969.

Depth	1	2	3	4	5	6	7	8	9	10	11	12
						May 15, 1968						
0	6.4	4.9	5.6	4.5	4.3	5.1	5.8	7.2	4.2	5.1	5.1	4.3
1	5.7	5.6	5.9	5.4	4.3	5.4	6.2	6.9	5.3	6.7	6.1	5.1
3	5.6	7.6	7.6	8.1	8.3	7.7	7.4	8.5	8.6	8.2	8.6	7.7
5	-	7.5	7.8	8.4	8.3	8.0	7.8	8.8	8.6	8.5	8.5	8.0
7	-	-	8.0	8.4	8.3	8.2	8.0	9.0	8.8	8.8	8.6	8.2
11	-	-	6.7	8.4	7.6	7.4	7.7	8.3	8.8	8.5	7.8	7.7
15	-	-	5.6	6.0	7.2	5.6	7.5	7.7	8.6	8.6	8.2	7.8
20	-	-	-	8.0	8.0	0.5	7.8	8.6	8.6	8.6	8.3	5.9
25	-	-	-	7.2	5.0	-	7.8	7.5	8.8	8.6	5.1	5.1
30	-	-	-	6.0	2.7	-	4.6	6.6	8.5	8.5	8.0	4.6
35	-	-	-	4.8	3.8	-	6.7	5.8	6.4	7.8	7.2	4.3
40	-	-	-	5.2	-	-	5.1	6.7	7.2	8.0	6.6	4.3

Depth	3	4	5	6	7	8	9	11
				July 3, 1968				
0	1.6	2.7	3.4	3.4	4.8	3.8	3.4	7.2
1	1.8	2.2	4.5	2.9	4.8	4.0	3.7	7.0
2	2.2	3.5	4.0	2.7	5.0	5.1	4.8	7.0
3	3.7	5.1	-	4.3	5.3	5.8	5.0	7.2
4	2.4	5.9	5.9	5.0	6.1	6.4	5.9	7.7
5	5.0	5.9	5.9	5.6	6.4	6.1	6.4	7.8
7	4.8	5.9	6.1	5.9	6.2	7.0	6.7	7.5
11	5.4	6.6	6.2	6.1	7.0	7.0	4.6	8.2
14	5.0	-	-	-	-	-	-	-
15	-	4.8	6.2	4.3	5.8	5.8	5.1	8.0
20	-	5.8	6.2	4.5	6.1	6.1	6.9	8.3
25	-	6.6	6.1	2.6	5.6	6.7	7.2	8.2
30	-	5.8	3.7	-	5.9	5.8	7.2	7.5
35	-	4.3	-	-	5.6	5.8	5.8	6.6
40	-	-	-	-	6.4	4.3	4.8	6.7

TABLE 3A (Continued)
Dissolved Oxygen Concentrations (mg/l) With Depth (Meters) in Ward Cove and Tongass Narrows, 1968-1969.

Depth	3	4	5	6	7	8	9	11	14
					July 8, 1968				
0	8.2	7.4	-	-	-	8.0	-	8.6	-
1	8.3	8.3	-	-	-	8.3	-	8.6	-
2	8.5	8.3	-	-	-	8.3	-	8.6	8.6
7	8.2	8.3	-	-	-	7.8	-	7.7	-
10	8.0	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	7.7	-	-	-
20	-	7.2	-	-	-	-	-	6.2	7.4
25	-	-	-	-	-	6.7	-	-	-
30	-	5.6	-	-	-	-	-	6.9	7.0
35	-	-	-	-	-	4.6	-	-	-
39	-	3.7	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	5.9	-
45	-	-	-	-	-	5.4	-	-	-
55	-	-	-	-	-	-	-	4.5	-

October 8, 1968

Depth	2	5	6	8	11	12	14	15
0	8.4	3.0	4.4	3.2	2.1	2.3	4.8	8.3
1	3.9	3.2	2.9	2.4	2.8	3.6	5.9	8.1
3	3.9	4.7	4.5	5.4	5.5	4.3	6.1	-
5	4.3	5.4	5.0	6.7	6.8	5.6	5.9	-
7	-	-	-	-	-	-	7.2	-
10	-	5.5	1.9	7.5	7.6	5.8	-	7.9
15	-	5.9	-	7.6	7.6	6.3	-	-
29	-	2.9	-	-	-	-	-	-

TABLE 3A (Continued)

Dissolved Oxygen Concentrations (mg/l) With Depth (Meters) in Ward Cove and Tongass Narrows, 1968-1969.

Depth	2	5	6	8	11	12	15
					April 13, 1969		
0	11.4	7.7	8.2	8.0	8.5	7.1	10.3
1	9.5	8.3	8.3	8.4	8.9	8.1	9.7
2	9.9	8.9	8.9	9.4	9.2	8.4	9.6
3	9.9	9.0	9.1	9.5	9.3	8.7	9.8
4	-	-	9.3	9.5	9.2	8.9	9.7
5	9.8	9.1	9.4	9.4	9.3	9.0	9.7
7	9.7	9.2	9.4	9.3	9.3	8.9	9.6
10	9.5	9.3	9.1	8.7	-	8.9	9.5
14	7.9	9.4	8.1	9.1	-	8.9	9.4

TABLE 4A

Estimated Percentages of Bottom-Associated Animals and Animal Fragments in Samples from Ward Cove and Tongass Narrows, 1968 and 1969.

Station Number	Screen Size	Wood Fibers and Fragments	Fecal Pellets	Foraminifera	Rocks	Mollusk Shells and Fragments	Diatoms	Sponge Spicules	Echinoid Spines	Ostracods	Misc. 1% or less
						May 15, 1968					
5	2mm	99	-	-	1	1	-	-	-	-	-
5	250	97	-	1	2	.1	-	-	-	1	-
6	2mm	35-40	-	-	50	10-15	-	-	-	-	worm casings
6	250	70	25	1	2-3	1	-	-	-	.1	worm casings
9	2mm	99	-	-	.01	1	-	-	-	-	fish vertebra
9	250	10	85-90	1	1	1	.1	1	-	-	vertebra, scales
10	250	40-60	40-60	.01	.1	1	.1	-	-	-	fish scales
11	2mm	50	-	-	1	50	-	-	-	-	fish scale
11	250	10	85-90	1	.1	1	.1	1	-	.1	vertebra, scale
13	2mm	1	-	-	30-40	60-70	-	-	1	-	casings, Bryosoa
13	250	5	40-50 (woody)	3-5	5	30-40	-	1	1	-	casings, Bryosoa
14	2mm	1-2	-	-	90	5-10	-	-	-	-	Bryozoa
14	250	5	80	2	5-10	5	-	1	.01	.1	-
						October 9, 1968					
2	125	10	50-70 (woody)	.1	30-40	1	1	-	-	-	Crustacean
5	125	99		1	1	.1	.1	-	-	.1	
8	125	10-15	75-80	2-3	1	1	10-15	1-2	-	1	
11	125	15	70	3	1	1	10-15	2	-	1	

TABLE 5A

Length-Frequency Distribution of Blue Mussels, Mytilus Edulis, at 10 Selected Stations in Ward Cove and Tongass Narrows, May and July, 1968.

Station Number										Length	July 1968								
May 1968																			
1	2	3	4	5	6	7	8	9	10	mm	1	2	3	4	5	6	7	8	9	10
164	75	33	8	-	4	-	-	9	58	1	*800	*500	45	190	4	1	-	38	158	357
159	57	56	17	9	28	-	-	17	67	2	38	70	26	2	16	15	-	-	34	88
53	28	17	18	18	35	-	2	13	12	3	149	103	60	8	54	34	-	2	25	107
26	14	14	18	35	71	-	1	12	13	4	169	102	60	20	103	54	3	1	29	112
20	12	8	24	33	69	-	6	18	9	5	196	88	68	18	117	79	4	4	39	104
14	11	6	42	31	48	-	12	20	5	6	117	46	44	46	109	72	10	11	50	79
12	12	2	34	35	33	-	17	33	4	7	96	55	34	53	62	83	10	12	36	55
13	21	0	43	42	28	2	21	28	7	8	62	29	41	53	48	59	3	13	47	50
14	12	6	31	31	20	3	14	30	13	9	36	22	21	43	31	46	7	16	34	32
12	19	13	39	12	13	5	14	32	6	10	37	27	23	75	26	32	-	26	31	26
12	18	10	24	10	7	8	14	18	12	11	37	19	10	70	13	25	8	18	22	26
13	17	7	29	22	6	10	13	17	13	12	19	22	8	59	7	10	1	26	27	33
16	15	16	26	6	5	8	10	15	13	13	21	12	8	58	6	9	1	16	16	20
12	19	5	15	3	9	2	7	15	14	14	16	16	12	40	3	5	1	10	11	16
19	17	8	17	2	0	4	3	10	18	15	16	33	6	33	1	3	-	6	7	18
23	22	6	8	4	10	3	4	8	11	16	11	18	10	33	1	2	2	10	4	8
17	12	7	6	-	4	4	4	17	19	17	10	30	11	21	1	1	-	3	4	10
17	24	9	9	1	6	3	6	8	23	18	4	28	10	16	-	1	1	8	8	6
14	13	11	7	-	7	2	4	19	11	19	7	26	7	12	-	1	-	2	10	12
17	17	9	2	2	5	-	1	9	19	20	6	26	11	10	-	1	-	1	1	11
16	14	8	6	5	0	3	-	10	16	21	6	20	9	10	-	2	1	2	3	11
11	9	13	1	-	3	-	-	6	18	22	6	23	8	7	-	1	-	3	3	6
16	9	14	3	-	2	-	-	9	18	23	9	15	9	3	-	2	1	-	2	7
12	14	17	-	1	1	1	-	6	17	24	8	19	8	5	-	-	-	1	4	9
8	16	10	2	-	4	-	-	3	12	25	8	16	9	4	-	1	-	1	1	8
5	12	7	-	-	2	-	-	6	9	26	14	6	10	-	-	-	-	-	1	8
9	17	13	2	-	1	-	-	6	9	27	10	12	13	-	-	1	-	1	2	9
11	9	12	1	-	2	-	-	7	7	28	8	14	7	1	-	-	-	1	3	9
9	4	10	-	-	-	-	1	2	7	29	7	10	10	1	-	1	-	1	2	3
12	9	13	1	-	1	-	-	6	9	30	3	11	7	-	-	1	-	-	-	3
6	13	18	-	-	2	-	-	4	7	31	5	4	9	-	-	1	-	1	1	2
10	14	11	-	-	4	-	-	3	8	32	5	7	7	-	-	-	-	-	-	2
11	12	7	1	-	2	-	-	3	5	33	7	3	6	1	-	2	-	-	-	2
6	6	6	1	-	-	-	-	-	15	34	5	4	10	1	-	1	-	-	1	1
4	10	7	-	-	-	-	-	1	11	35	4	4	6	2	-	-	-	-	-	-
9	7	5	-	-	-	-	-	1	6	36	5	4	2	-	-	-	-	1	1	1
4	5	7	-	-	-	-	-	2	3	37	5	5	8	1	-	1	-	-	-	2
3	8	2	-	-	1	-	-	1	2	38	2	2	9	-	-	-	-	-	1	1
5	6	1	-	-	1	-	-	-	2	39	1	1	1	-	-	1	-	-	-	1
4	4	1	-	-	2	-	-	-	3	40	6	6	1	-	-	1	-	-	-	-
5	8	2	-	-	-	-	-	-	3	41	1	-	3	-	-	-	-	-	-	-
2	5	3	-	-	1	-	-	-	2	42	-	-	4	-	-	-	-	1	-	-
4	3	1	-	-	1	-	-	-	-	43	1	1	3	-	-	1	-	-	-	2
2	3	1	-	-	1	-	-	-	-	44	1	1	2	-	-	-	-	-	-	-
2	2	-	-	-	-	-	-	-	-	45	-	1	5	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	2	46	2	-	1	-	-	-	-	-	-	-
2	2	1	-	-	-	-	-	-	1	47	-	-	1	-	-	1	-	-	-	-
2	-	1	-	-	-	-	-	-	-	48	1	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	49	-	-	-	-	-	-	-	-	-	-
										50					-					
1	1	-	-	-	-	-	-	-	-	51	-	-	1	-	-	-	-	-	-	-
-	1	-	-	-	-	-	-	-	-	52										
1	-	-	-	-	-	-	-	-	-	55										
1	-	-	-	-	-	-	-	-	-	61										
943	661	434	435	291	480	58	159	418	550		1978	1461	605	906	602	551	53	236	618	1251

TABLE 6A

Percentages of Phytoplanktons in Samples from Ward Cove and Tongass Narrows, 1968-1969.

	Station Numbers	Coscinodiscus & Thallisiosira	Chaetoceros	Ditylum	Thallisiothrix	Nitzschia	Skeletonema	Biddulphia	Corethron	Rhizoselenia	Fragillaria	Unidentified	Ceratium	Peridinium	Total Counted	Depth of Haul-Meters	Direction-Vertical or Oblique
October, 1968	15	60	17	1	-	12	-	-	-	-	-	-	5	5		25	0
	11	54	3	-	3	35	-	1	-	-	-	-	2	3		25	0
	8	39	2	1	2	48	3	-	-	-	-	-	2	2		25	0
	5	72	5	-	-	22	-	-	-	-	-	-	-	1		25	0
	2	88	-	-	-	10	-	1	-	-	-	-	1	-		10	v
December, 1968	15	79	14	-	-	-	-	-	-	-	-	-	7	-	97	2	v
	15	55	24	5	12	-	-	1	-	-	1	-	4	-	218	30	0
	11	95	3	2	-	-	-	-	-	-	-	-	-	-	62	2	v
	11	85	8	2	3	-	-	1	-	1	-	-	1	-	183	30	0
	8	100	-	-	-	-	-	-	-	-	-	-	-	-	52	2	v
	8	91	4	2	-	-	-	-	-	-	2	-	-	1	114	30	0
	6	100	-	-	-	-	-	-	-	-	-	-	-	-	118	20	v
	5	100	-	-	-	-	-	-	-	-	-	-	-	-	38	2	v
	5	91	1	1	5	-	-	1	-	-	-	-	-	1	117	30	v
	2	91	-	-	-	-	-	-	-	-	-	9	-	-	56	2	v
	2	95	-	3	-	-	-	-	-	-	-	2	-	-	66	8	v
	190*	55	19	3	9	-	-	2	1	-	-	11	-	-	109		
		82	11	3	2	-	-	2	5	-	-	0	-	-	220		

TABLE 6A (Continued)

Percentages of Phytoplanktons in Samples from Ward Cove and Tongass Narrows, 1968-1969.

	Station Numbers	Coscinodiscus & Thallisiosira	Chaetoceros	Ditylum	Thallisiothrix	Nitzschia	Skeletonema	Biddulphia	Corethron	Rhizoselenia	Fragillaria	Unidentified	Ceratium	Peridinium
		Phytoplankton-Relative Abundance R-Rare O-Occasional C-Common												
April, 1969	15	C	C	R	-	-	O	R	-	-	R	R	R	O
	11	C	C	R	-	-	O	R	-	-	R	R	-	O
	8	C	C	R	-	-	O	-	-	-	R	R	R	O
	6	O	O	-	-	-	R	-	-	-	R	-	-	R
	5	C	C	R	-	-	O	R	-	-	-	-	-	R
	2	O	O	R	R	-	R	R	-	-	R	R	-	R
	Near Outfall	R	-	-	-	-	-	-	-	-	-	-	-	-

* In Tongass Narrows South of Ketchikan